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# Screening Tests of Compounds as Fumigants for Eggs and Larvae of the Oriental Fruit Fly

F. G. HINMAN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The movement of fresh fruit and vegetable hosts of fruit flies from Hawaii to mainland markets is permitted on condition that a satisfactory treatment to eliminate possible infestations has been applied. Both vapor-heat sterilization and methyl bromide fumigation are approved treatments for certain commodities, but their usefulness is limited because of their injurious effect on many of the fruit fly hosts produced in Hawaii. At concentrations toxic to fruit fly eggs and larvae, ethylene dibromide is less injurious than methyl bromide or vapor heat to a number of commodities (Balock 1951), but even this fumigant injures some kinds of fresh fruits and vegetables. In a continuing search for materials that will overcome the disadvantages of presently approved commodity treatments, 189 materials have been tested on naked eggs and larvae of the oriental fruit fly, *Dacus dorsalis* Hendel, at the Honolulu laboratory of the Bureau of Entomology and Plant Quarantine. In previous tests, which indicated the initial promise of ethylene dibromide and ethylene chlorobromide (1-bromo-2-chloroethane), Balock & Lindgren (1951) screened 53 compounds and mixtures.

METHOD OF TESTING.—The methods used were essentially the same as those developed by Balock & Lindgren (1951). One hundred eggs, 23 to 26 hours old, on moistened blotting paper in open petri dishes and 25 third-instar larvae in each of two 50-ml. beakers were placed on a platform about 3 inches above the bottom of a 5-gallon friction-top tin can. The materials were applied with a microburette or pipette through a hole in the center of the friction-top lid to a filter paper on a wire screen suspended about 3 inches below.

A few compounds, too viscous to be applied by pipette, were applied from a larger vessel and the amount used was determined by weighing the vessel before and after application.

The exposure period was 2 hours at $75 \pm 2°$ F. After exposure the eggs and larvae were aired and held for observation at room temperature. Readings were made 24 and 48 hours after fumigation. The results were corrected for mortalities occurring in comparable lots of untreated eggs and larvae. Mortality curves were drawn for each material that killed 50 per cent or more of either stage at a dosage of 0.1 ml. of material applied to the filter paper per liter of chamber capacity, or approximately 0.76 gallon per 1000 cubic feet. From these curves, based on amounts introduced into the chambers rather than actual concentrations in the atmosphere, the LD-50 and LD-95 for each material were determined.

Specific gravities were used in transposing milliliters to milligrams. Where specific gravity data were not available, measured volumes were weighed to determine densities.

RESULTS.—The results of the screening tests are summarized in table 1. The comparative effectiveness of the 50 most promising materials, classified according to their toxicity to eggs and/or larvae of the oriental fruit fly, is indicated in table 2.

Most of the compounds tested contained halogens, because the work previously mentioned indicated that such materials offered the most promise of providing additional useful fumigants for the

**Table 1.—Effectiveness of various compounds used as fumigants against naked eggs and third-instar larvae of the oriental fruit fly. Milligrams per liter giving 50 and 95 per cent mortality 48 hours after exposure.**

| Compound | Eggs | | Larvae | |
|---|---|---|---|---|
| | LD-50 | LD-95 | LD-50 | LD-95 |
| *Halogenated Aliphatic Hydrocarbons, Saturated* | | | | |
| Chlorides | | | | |
| Methane, dichloro- (methylene chloride) | >136 | >136 | >136 | >136 |
| Chloroform | >153 | >153 | >153 | >153 |
| Carbon tetrachloride | >168 | >168 | >168 | >168 |
| Ethane, 1,1,2-trichloro- | 100 | >150 | 66 | 145 |
| Ethane, 1,1,2,2-tetrachloro- | 25 | 68 | 20 | 43 |
| Ethane, pentachloro- | >171 | >171 | 16 | 60 |
| Propane, 1-chloro- (*n*-propyl chloride) | >91 | >91 | >91 | >91 |
| Propane, 1,3-dichloro- | >123 | >123 | 45 | 115 |
| Propane, 2,2-dichloro- | >112 | >112 | >112 | >112 |
| Propane, 1,1,2-trichloro- | >126 | >126 | 26 | 92 |
| Propane, 1,2,2-trichloro- | >127 | >127 | 80 | 120 |
| Propane, 1,1,1,2-tetrachloro- | 65 | >135 | 28 | >135 |
| Propane, 1,1,2,3-tetrachloro- | >144 | >144 | 63 | >144 |
| Propane, 1,2,2,3-tetrachloro- | >142 | >142 | 85 | >142 |
| Propane, 1,1,2,2,3-pentachloro- | >176 | >176 | >176 | >176 |
| Butane, 1-chloro- (*n*-butyl chloride) | >135 | >135 | >135 | >135 |
| Butane, 2-chloro- (*sec*-butyl chloride) | >89 | >89 | >89 | >89 |
| Butane, 2-chloro-2-methyl- (*t*-amyl chloride) | >89 | >89 | >89 | >89 |
| Butane, 1,4-dichloro- | 12 | >110 | >110 | >110 |
| Pentane, 1-chloro- (*n*-amyl chloride) | >90 | >90 | 42 | 56 |
| Pentane, 1,2-dichloro- | >106 | >106 | >106 | >106 |
| Hexane, 1-chloro- (*n*-hexyl chloride) | >89 | >89 | >89 | >89 |
| Octane, 1-chloro- (*n*-octyl chloride) | >89 | >89 | >89 | >89 |
| Decane, 1-chloro- (*n*-decyl chloride) | >89 | >89 | >89 | >89 |
| Hexadecane, 1-chloro- (*n*-hexadecyl chloride) | >86 | >86 | >86 | >86 |
| Bromides | | | | |
| Methane, dibromo- (methylene dibromide) | 18 | 38 | 132 | 218 |
| Bromoform | 42 | 190 | >305 | >305 |
| Carbon tetrabromide (solid) | >250 | >250 | 75 | >250 |
| Ethane, bromo-[1] | 121 | 194 | 201 | >300 |
| Ethane, 1,1-dibromo- | >213 | >213 | >213 | >213 |
| Ethane, 1,1,2,2-tetrabromo- | >151 | >151 | >151 | >151 |
| Propane, 1-bromo- (*n*-propyl bromide)[1] | 52 | 93 | 88 | 130 |
| Propane, 2-bromo- (*sec*-propyl bromide) | >202 | >202 | >202 | >202 |
| Propane, 1-bromo-2-methyl- (isobutyl bromide) | >195 | >195 | >195 | >195 |
| Propane, 2-bromo-2-methyl-(*tert*-butyl bromide) | >188 | >188 | 164 | >188 |
| Propane, 1,2-dibromo- | 6.1 | 18 | 0.5 | 1.8 |
| Propane, 1,3-dibromo-[1] | <5.1 | 5.5 | 8.1 | 18 |
| Propane, 1,2-dibromo-2-methyl- (isobutylene bromide) | >179 | >179 | 33 | 130 |
| Butane, 1-bromo-2-methyl- (*pri-act*-anyl bromide) | >188 | >188 | 54[1] | 215[1] |
| Butane, 1-bromo-3-methyl- (isoamyl bromide) | >187 | >187 | 65 | 131 |
| Butane, 1-bromo-2-ethyl- | >173 | >173 | 48 | >173 |
| Butane, 2-bromo- (*sec*-butyl bromide) | >194 | >194 | >194 | >194 |
| Butane, 2-bromo-2-methyl- (*t*-amyl bromide) | >183 | >183 | >183 | >183 |
| Butane, 1,2-dibromo- | 5.5 | 8.7 | 4.1 | 7.8 |
| Butane, 1,3-dibromo- | >184 | >184 | 14.5 | 31 |
| Butane, 1,4-dibromo- | 40 | >188 | 21 | 45 |
| Butane, 2,3-dibromo- | >170 | >170 | 3.3 | >170 |
| Pentane, 1-bromo- (*n*-amyl bromide) | 38 | 81 | 44 | 92 |
| Pentane, 2-bromo- (*sec*-amyl bromide) | >162 | >162 | 88 | >162 |
| Pentane, 1,2-dibromo- | >170 | >170 | 0.6 | 1.6 |
| Pentane, 1,4-dibromo- | >162 | >162 | >162 | >162 |
| Pentane, 1,5-dibromo- | 3.2 | >174 | >174 | >174 |
| Pentane, 2,4-dibromo- | >156 | >156 | >156 | >156 |
| Hexane, 1-bromo- (*n*-hexyl bromide) | >119 | >119 | >119 | >119 |
| Hexane, 1-bromo-2-ethyl- | >107 | >107 | >107 | >107 |
| Hexane, 1-bromo-3,5,5-trimethyl- | >105 | >105 | >105 | >105 |
| Hexane, 2,5-dibromo- | >150 | >150 | >150 | >150 |
| Heptane, 1-bromo- (*n*-heptyl bromide) | 16 | >116 | 40 | >116 |

[1] Mortality at 24 hours.

| Compound | Eggs | | Larvae | |
|---|---|---|---|---|
| | LD-50 | LD-95 | LD-50 | LD-95 |
| Heptane, 2 bromo- (*sec*-heptyl bromide) | >143 | >143 | >143 | >143 |
| Octane, 1-bromo- (*n*-octyl bromide) | 13 | 21 | >113 | >113 |
| Octane, 2-bromo- (*sec*-octyl bromide) | >111 | >111 | >111 | >111 |
| Nonane, 1-bromo- (*n*-nonyl bromide) | >110 | >110 | >110 | >110 |
| Decane, 1-bromo- (*n*-decyl bromide) | >109 | >109 | >109 | >109 |
| Dodecane, 1-bromo- (*n*-dodecyl bromide) | >100 | >100 | >100 | >100 |
| Tetradecane, bromo- | >97 | >97 | >97 | >97 |
| Hexadecane, bromo- | >96 | >96 | >96 | >96 |
| Iodides | | | | |
| Methane, diiodo- (methylene iodide) | 0.4 | 0.6 | 0.06 | 0.7 |
| Ethane, iodo- | 5 | 7 | 0.05 | 0.3 |
| Propane, 1-iodo- (*n*-propyl iodide) | 2 | 5.5 | 20 | 35 |
| Propane, 2-iodo- (*sec*-propyl iodide) | 16 | 32 | <0.9 | 135 |
| Propane, 1-iodo-2-methyl- (isobutyl iodide) | 6.4 | 16 | 16 | 45 |
| Butane, 1-iodo- (*n*-butyl iodide) | <4.1 | <4.1 | 11 | 22 |
| Butane, 2-iodo- (*sec*-butyl iodide) | 20 | 36 | 5.1 | 41 |
| Butane, 1-iodo-3-methyl- (isoamyl iodide) | 7.5 | 14 | 14.5 | 31 |
| Pentane, 1-iodo- (*n*-amyl iodide) | <3.9 | <3.9 | 9.3 | 20.2 |
| Hexane, 1-iodo- (*n*-hexyl iodide) | <0.7 | <1.1 | <0.7 | <0.7 |
| Heptane, 1-iodo- (*n*-heptyl iodide) | <0.8 | <0.8 | <0.8 | <0.8 |
| Octane, 1-iodo- (*n* octyl iodide) | 1.3 | 3.0 | 1.9 | — |
| Decane, 1-iodo- (*n*-decyl iodide) | >128 | >128 | >128 | >128 |
| Chlorobromides | | | | |
| Methane, bromochloro- | 40 | 77 | 60 | 110 |
| Methane, dibromochloro- | >240 | >240 | >240 | >240 |
| Methane, bromodichloro- | >201 | >201 | >201 | >201 |
| Methane, bromotrichloro- | 37 | 210 | 2.9 | 5.5 |
| Methane, dibromodichloro- | >231 | >231 | 3.0 | 5.7 |
| Ethane, bromotrichloro- | 100 | >192 | 2.5 | 4.3 |
| Ethane, 1,2-dibromo-1,1-dichloro- | >232 | >232 | >232 | >232 |
| Ethane, 1,2-dibromo-1,2-dichloro- | >221 | >221 | >221 | >221 |
| Ethane, 1,2-dibromo-1,1,2-trichloro- | >223 | >223 | >223 | >223 |
| Ethane, 1,2-dibromo-1,1,1,2-tetrachloro-(solid) | >500 | >500 | >500 | >500 |
| Propane, 2-bromo-1-chloro- | 17 | 39 | <1.6 | 28 |
| Propane, 1-bromo-3-chloro- | 15 | 27 | 24 | 44 |
| Propane, 1,2-dibromo-3-chloro- | 175 | >206 | 25 | >206 |
| Propane, 1,2-dibromo-1,3-dichloro- | >207 | >207 | >207 | >207 |
| Butane, 1-bromo-3-chloro- | 18 | 29 | 13 | 19 |
| Butane, 1-bromo-4-chloro- | >230 | >230 | 100 | >230 |
| Butane, 2,3-dibromo-1,4-dichloro- (solid) | >500 | >500 | >500 | >500 |
| Chlorofluorides | | | | |
| Ethane, 1,2-dichloro-1,1-difluoro- | >145 | >145 | >145 | >145 |
| Ethane, 1,1-dichloro-2,2-difluoro- | >143 | >143 | >143 | >143 |
| Ethane, 1,2,2-trichloro-1-fluoro- | 137 | >148 | 56 | 110 |
| Ethane, 1,1,2-trichloro-2,2-difluoro- | >158 | >158 | >158 | >158 |
| Propane, 1,2-dichloro-2-fluoro- | >129 | >129 | 40 | 52 |
| Chloroiodides | | | | |
| Butane, 1-chloro-4-iodo- (in carbon tetrachloride)[2] | | | | |
| 2 per cent | 0.3 | 0.7 | 0.1 | 0.3 |
| 10 per cent | 0.1 | 0.3 | <0.9 | <0.9 |
| *Halogenated Aliphatic Hydrocarbons, Unsaturated* | | | | |
| Propene, 1-chloro- | >88 | >88 | >88 | >88 |
| Propene, 1,1,3,3-tetrachloro- | >147 | >147 | 2.2 | 10 |
| 2-Butene, 1,4-dichloro- | 3.6 | 6.1 | 2.1 | 3.3 |
| Propene, 1-bromo- | >146 | >146 | >146 | >146 |
| Propene, 1,1-dibromo- | 135 | >191 | 55 | >191 |
| Propene, 3-iodo- (allyl iodide) | 4.2 | 7.2 | 0.3 | 0.8 |
| 2-Propene, 2,3-dichloro,1,1-difluoro- | 110 | >183 | >183 | >183 |
| *Halogenated Cycloparaffins* | | | | |
| Cyclopentane, chloro- | 9 | 31 | — | 24 |
| Cyclopentane, bromo- | 9 | 16 | 7.5 | 14 |
| Cyclohexane, chloro- | >104 | >104 | 90 | >104 |
| Cyclohexane, bromo- | >136 | >136 | >136 | >136 |

[2] Weight of carbon tetrachloride not included in calculating dosage-mortality.

| Compound | Eggs | | Larvae | |
|---|---|---|---|---|
| | LD-50 | LD-95 | LD-50 | LD-95 |
| Cyclohexane, 1,2-dibromo- | >173 | >173 | >173 | >173 |
| Cyclohexane, fluoro- | >89 | >89 | >89 | >89 |
| Cyclohexane, iodo- | 2.5 | 7.6 | 0.2 | 2.0 |
| *Halogenated Aromatic Hydrocarbons* | | | | |
| Chlorides | | | | |
| Benzene, α-chloro-trimethyl- | >100 | >100 | >100 | >100 |
| Toluene, α,α-dichloro- | >128 | >128 | >128 | >128 |
| Toluene, α-chloro-ethyl- | >100 | >100 | >100 | >100 |
| Xylene, α-chloro- | 9 | 27 | 18 | 43 |
| Bromides | | | | |
| Benzene, bromo- | 15 | 31 | 61 | 178 |
| Benzene, (1-bromoethyl)- | >130 | >130 | >130 | >130 |
| Benzene, (2-bromoethyl)- | >130 | >130 | >130 | >130 |
| Styrene, α-bromo- | >143 | >143 | >143 | >143 |
| Toluene, α-bromo- | 5.7 | 13 | 4.7 | 11 |
| Toluene, 2,5-dibromo- | >191 | >191 | >191 | >191 |
| p-Xylene, α-bromo- | >203 | >203 | >203 | >203 |
| Fluorides | | | | |
| Toluene, α,α,α-trifluoro- | >122 | >122 | >122 | >122 |
| Xylene, α,α,α,α′,α′,α′-hexafluoro- | >133 | >133 | >133 | >133 |
| Chlorofluorides | | | | |
| Toluene, *o*-chloro-α,α,α-trifluoro- | >132 | >132 | >132 | >132 |
| Toluene, *m*-chloro-α,α,α-trifluoro- | >131 | >131 | >131 | >131 |
| Toluene, *p*-chloro-α,α,α-trifluoro- | >128 | >128 | >128 | >128 |
| *Hydrocarbons* | | | | |
| Pentane, 2,2,4-trimethyl- | >73 | >73 | >73 | >73 |
| Hexane | >67 | >67 | >67 | >67 |
| Heptane | >70 | >70 | >70 | >70 |
| Decane | >75 | >75 | >75 | >75 |
| *Alcohols* | | | | |
| Ethanol, 2-chloro- | 27 | >100 | 7 | 12 |
| Ethanol, 2-bromo- | 20 | 53 | 5 | 9.0 |
| Propyl alcohol | >82 | >82 | >82 | >82 |
| Isopropyl alcohol | >80 | >80 | >80 | >80 |
| 2-Propanol, 1-chloro- | 58 | >113 | 5.2 | 8.9 |
| 2-Propene-1-ol, 2-chloro- | 29 | >120 | 5.2 | 5.8 |
| Butyl alcohol | >82 | >82 | >82 | >82 |
| *sec*-Butyl alcohol | >82 | >82 | >82 | >82 |
| Isobutyl alcohol | >82 | >82 | >82 | >82 |
| *tert*-Butyl alcohol | >83 | >83 | >83 | >83 |
| 1-Butanol, 4-chloro- | >104 | >104 | >104 | >104 |
| 1,4-Butanediol | >104 | >104 | >104 | >104 |
| *Aldehydes* | | | | |
| Bromal | >235 | >235 | >235 | >235 |
| Propionaldehyde | 58 | 100 | 15 | 38 |
| Paraldehyde | >101 | >101 | >101 | >101 |
| Metaldehyde (solid) | >500 | >500 | >500 | >500 |
| Crotonaldehyde | 6.5 | 11 | 5.5 | 10 |
| *Ketones* | | | | |
| 2-Butanone | >82 | >82 | >82 | >82 |
| 2-Butanone, 3-methyl | >83 | >83 | >83 | >83 |
| 2-Butanone, 3-hydroxy- | >102 | >102 | >102 | >102 |
| 2,3-Butanedione | >101 | >101 | >101 | >101 |
| Acetophenone | >105 | >105 | >105 | >105 |
| Propiophenone | >103 | >103 | >103 | >103 |
| *Ethers* | | | | |
| Ether, chloromethyl methyl | >108 | >108 | >108 | >108 |
| Triethylene glycol | >115 | >115 | >115 | >115 |
| Ethyl ether | >73 | >73 | >73 | >73 |
| Ether, ethyl vinyl | >78 | >78 | >78 | >78 |
| Ether, *bis*(2-bromethyl)[1] | 3.2 | 6.4 | 50 | 118 |

[1] Mortality at 24 hours.

| Compound | Eggs | | Larvae | |
|---|---|---|---|---|
| | LD-50 | LD-95 | LD-50 | LD-95 |
| *Oxides* | | | | |
| Epichlorohydrin | 15 | 24 | 1.9 | 3.5 |
| Epibromohydrin | 4.7 | 8.9 | 2.3 | 4.0 |
| *Esters* | | | | |
| Formic acid, chloro-, ethyl ester | >116 | >116 | 4.2 | 7.3 |
| Acetic acid, ethyl ester | >92 | >92 | >92 | >92 |
| Acetic acid, dichloro-, ethyl ester | >131 | >131 | >131 | >131 |
| Acetic acid, butyl ester | >90 | >90 | >90 | >90 |
| Acetic acid, isobutyl ester | >89 | >89 | >89 | >89 |
| Propionic acid, methyl ester | >97 | >97 | >97 | >97 |
| Propionic acid, ethyl ester | >90 | >90 | >90 | >90 |
| *Acids* | | | | |
| Acetic acid | >107 | >107 | 36 | 56 |
| Acetic anhydride | >110 | >110 | 20 | 110 |
| Butyric acid, α-bromo- | 160 | 222 | >222 | >222 |
| *Acid Halides* | | | | |
| Acetyl chloride | 33 | 80 | 26 | 65 |
| Propionyl chloride | >109 | >109 | >109 | >109 |
| Propionyl bromide | >155 | >155 | >155 | >155 |
| *Nitrogen and Sulfur Compounds* | | | | |
| Ethane, nitro- | >107 | >107 | 39 | 118 |
| Ethylenediamine | >92 | >92 | >92 | >92 |
| Methylamine hydrochloride | >104 | >104 | >104 | >104 |
| Butylamine | 8 | 13 | 23 | 38 |
| Morpholine | >102 | >102 | >102 | >102 |
| Pyridine | >102 | >102 | >102 | >102 |
| Toluene, α,α,α-trifluoro-*m*-nitro | >145 | >145 | >145 | >145 |
| *m*-Toluidine, α,α,α-trifluoro- | >124 | >124 | >124 | >124 |
| Isothiocyanic acid, allyl ester | 2.3 | 4.0 | <0.5 | 1.2 |
| 1-Butanethiol | 25 | 31 | 22 | 75 |

[1] Mortality in 24 hours.

fruit fly. In general, as found by Roark & Cotton (1929) and by Ferguson & Pirie (1948), the iodides were more toxic than the bromides and the bromides were more toxic than the chlorides.

Although somewhat erratic in their performance, the iodides were the most toxic materials tested, comprising 7 of the 11 compounds that killed 95 per cent of both eggs and larvae at dosages of 10 mg. or less per liter (1 mg. per liter represents approximately 1/16 pound per 1000 cubic feet). The classification as survivors of all larvae still alive 48 hours after treatment was an inadequate measure of the toxicity of the iodides. These compounds inhibited pupation markedly, and some affected larvae lived for considerable periods of time. Even at high dosages a few larvae remained alive 48 hours after treatment although their ability to complete development was arrested. Methyl iodide at dosages of less than 5 mg. per liter killed 95 per cent of the immature stages within 24 hours (Balock & Lindgren 1951), but permitted oriental fruit flies to survive when infested papayas were fumigated in a large chamber with a much higher dosage of 2 pounds per 1000 cubic feet.

With the exception of the four most toxic iodides—1-iodohexane, 1-iodoheptane, 1-chloro-4-iodobutane and diiodomethane, none of the halogen compounds tested were as effective against both eggs and larvae of the oriental fruit fly as ethylene dibromide (Tables 2 and 3). 1-Chloro-4-iodobutane was more effective than 1-iodobutane.

Other bromides and chlorides tested might be considered as variations from the ethylene dibromide molecule by the addition, subtraction, or substitution of chlorine or bromine atoms with methyl groups added or subtracted when the carbon atoms in the molecule are other than two. Any such variation from the ethylene dibromide molecule resulted in reduced toxicity; 1-Bromo-2-chloroethane the next most toxic compound tested, re-

**Table 2.—Compounds killing 95 per cent of eggs and/or larvae of the oriental fruit fly at dosages of less than 50 mg. per liter within 48 hours after exposure.[1]**

| COMPOUND | EGGS | LARVAE |
|---|---|---|
| *Killing 95 per cent of both eggs and larvae* | | |
| Butane, 1-chloro-4-iodo- (in carbon tetrachloride)[2] | | |
| 2 per cent | 0.7 | 0.3 |
| 10 per cent | 0.3 | <0.9 |
| Methane, diiodo- (methylene iodide) | 0.6 | 0.7 |
| Heptane, 1-iodo- | <0.8 | <0.8 |
| Hexane, 1-iodo- | <1.1 | <0.7 |
| Isothiocyanic acid, allyl ester | 4.0 | 1.2 |
| Ethane, iodo- | 7.0 | 0.3 |
| Propene, 3-iodo- | 7.2 | 0.8 |
| 2-Butane, 1,4-dichloro- | 6.1 | 3.3 |
| Cyclohexane, iodo- | 7.6 | 2.0 |
| Epibromohydrin | 8.9 | 4.0 |
| Butane, 1,2-dibromo- | 8.7 | 7.8 |
| Propane, 1,2-dibromo- | 18 | 1.8 |
| Crotonaldehyde | 11 | 10 |
| Propane, 1-3-dibromo- | 5.5 | 18 |
| Pentane, 1-iodo- | <3.9 | 20 |
| Toluene, α-bromo- | 13 | 11 |
| Butane, 1-iodo- | <4.1 | 22 |
| Epichlorohydrin | 24 | 3.5 |
| Cyclopentane, bromo- | 16 | 14 |
| Propane, 1-iodo- | 5.5 | 35 |
| Butane, 1-iodo-3-methyl- | 14 | 31 |
| Butane, 1-bromo-3-chloro- | 29 | 19 |
| Butylamine | 13 | 38 |
| Cyclopentane, chloro- | 31 | 24 |
| Propane, 1-iodo-2-methyl | 16 | 45 |
| Propane, 2-bromo-1-chloro- | 39 | 28 |
| Xylene, α-chloro- | 27 | 43 |
| Propane, 1-bromo-3-chloro- | 27 | 44 |
| Butane, 2-iodo- | 36 | 41 |
| *Killing 95 per cent of the larvae* | | |
| Pentane, 1,2-dibromo- | >170 | 1.6 |
| Ethane, bromotrichloro- | >192 | 4.3 |
| Methane, bromotrichloro- | 210 | 5.5 |
| Methane, dibromodichloro- | 231 | 5.7 |
| 2-Propene-1-ol, 2-chloro- | >120 | 5.8 |
| Formic acid, chloro-, ethyl ester | >116 | 7.3 |
| 2-Propanol, 1-chloro- | >113 | 8.9 |
| Ethanol, 2-bromo- | 53 | 9.0 |
| Propene, 1,1,3,3-tetrachloro- | >147 | 10 |
| Ethanol, 2-chloro- | >100 | 12 |
| Butane, 1,3-dibromo- | >184 | 31 |
| Propionaldehyde | 100 | 38 |
| Ethane, 1,1,2,2-tetrachloro- | 68 | 43 |
| Butane, 1,4-dibromo- | >188 | 45 |
| *Killing 95 per cent of the eggs* | | |
| Octane, 1-iodo- | 3.0 | [3] |
| Ether, *bis*(2-bromoethyl) | 6.4 | 118[4] |
| Octane, 1-bromo- | 21 | >113 |
| 1-Butanethiol | 31 | 75 |
| Benzene, bromo- | 31 | 178 |
| Propane, 2-iodo- | 32 | 135 |
| Methane, dibromo- | 38 | 218 |

[1] Figures in milligrams per liter.
[2] Weight of carbon tetrachloride not included in dosage-mortality.
[3] High mortalities at low dosages, but not 95 per cent.
[4] 24 hours after exposure.

quired four times as many gram-moles per liter to kill 95 per cent of the eggs and larvae and the other bromides and chlorides required ten or more times as many (Table 3).

**Table 3.—Dosages of ethylene dibromide and related compounds to give 95 per cent mortality[1] of naked eggs and third-instar larvae of the oriental fruit fly.**

| COMPOUND | MILLIGRAMS PER LITER | | GRAM-MOLES PER LITER ($X^{10^{-6}}$) | |
|---|---|---|---|---|
| | Eggs | Larvae | Eggs | Larvae |
| Ethylene dibromide (Ethane, 1,2-dibromo-) | 0.8 | 0.6 | 3.9 | 3.2 |
| Ethane, 1-bromo-2-chloro- | <2.2 | 2.3 | <15 | 16 |
| Butane, 1,2-dibromo- | 8.7 | 7.8 | 40 | 36 |
| Propane, 1,2-dibromo- | 18 | 1.8 | 89 | 8.9 |
| Propane, 1,3-dibromo- | 5.5 | 18 | 27 | 89 |
| Ethane, 1,2-dichloro- | 5.9 | 21 | 60 | 212 |
| Methyl bromide | 25 | 19 | 263 | 200 |
| Butane, 1-bromo-3-chloro- | 29 | 19 | 180 | 118 |
| Propane, 2-bromo-1-chloro- | 39 | 28 | 248 | 178 |

[1] Mortalities determined 48 hours after exposure.

Alpha-bromotoluene, α-chloroxylene, bromocyclopentane, and chlorocyclopentane were toxic to both eggs and larvae. Bromocyclohexane and chlorocyclohexane were comparatively ineffective. (Table 1).

Three chlorofluorides with two fluorine atoms on the same carbon atom were ineffective. Such compounds are known to be chemically inert. On the other hand, two chlorofluorides containing only one fluorine atom were slightly more toxic to larvae than the corresponding unfluorinated chlorides, of which 1,2-dichloropropane was tested by Balock & Lindgren (1951).

Alkyl side chains seemed to be associated with a decrease in the toxicity of halogen compounds to the oriental fruit fly in almost all instances. These results are in agreement with those obtained by Ferguson & Pirie (1948) in their fumigation studies with the granary weevil, *Sitophilus granarius* (L.), in which they used a 5-hour exposure period. The greater stability and decreased reactivity of the iso-halide compounds were considered to be the reasons for their decreased toxicity to the granary weevil. In contrast to these findings, Roark & Cotton (1929) found that many branched-chain halogens were more toxic to the rice weevil, *Sitophilus oryza* (L.), than straight-chain halogens during an exposure period of 24 hours in the presence of absorptive grain. Perhaps the longer exposure period used in the latter tests

favored the more narcotic and less chemically reactive materials. Moreover, branched-chain materials, with lower boiling points and greater volatility, might penetrate the grain more readily and be absorbed to a lesser extent.

Technical bromochloropropene (principally 3-bromo-1-chloropropene), tested by Balock & Lindgren (1951), 3-iodopropene, and 1,4-dichloro-2-butene were the most toxic unsaturated halogenated hydrocarbons found. Since halogen atoms are most reactive when attached to a carbon atom adjoining a carbon atom with a double bond, the 1,4-dichloro-2-butene with two halogen atoms at such effective positions might be expected to be very reactive and this reactivity may account for its high toxicity. It was more effective than 3-chloropropene or 1,3-dichloropropene, both tested by Balock & Lindgren (1951), the former under the name allyl-chloride.

The toxicities of the various halogen compounds to oriental fruit fly eggs and larvae were also in close agreement with those reported by Ferguson & Pirie (1948) for granary weevil adults, but three exceptions may be noted. 1,2-Dichloroethane, dibromomethane, and 1,1,1-trichloroethane, the latter tested by Balock & Lindgren (1951), were much more effective against the eggs of the oriental fruit fly than they were against granary weevil adults. Alcohols and esters were more toxic to the granary weevil, as reported by Ferguson and Pirie, than to the oriental fruit fly, but the longer exposure period used in the granary weevil tests may have favored the performance of these materials. None of the nonhalogenated esters tested were effective against the oriental fruit fly, whereas the halogenated ester ethyl chloroformate was toxic to the larvae and, previously, Balock & Lindgren (1951) had found ethyl chloroacetate to be very toxic to both eggs and larvae.

The following halogen-substituted oxides and alcohols killed 95 per cent of the larvae at dosages of 3.5 to 12 mg. per liter: epichlorohydrin, epibromohydrin, 1-chloro-2-propanol, 2-bromoethanol, 2-chloroethanol, and 2-chloro-2-propene-1-ol. Only epibromohydrin killed 95 per cent of the eggs within this dosage range.

The results with all compounds screened at the Honolulu laboratory, including those previously reported by Balock & Lindgren (1951), are summarized in table 4. Of the 230 compounds tested thus far, 29 have been effective at low dosages against both naked eggs and naked larvae of the oriental fruit fly. Some of them have been tested to determine possible injurious effects on fresh fruits and vegetables. Only 2 of the 230, methyl bromide and ethylene dibromide, have come into commercial usage as approved fruit fly commodity treatments. 1-Bromo-2-chloroethane, another material indicated as promising in the earlier screening tests of Balock & Lindgren (1951), has passed many of the subsequent developmental tests successfully, and it may soon be possible to recommend its use as a quarantine treatment. Further research may indicate worthwhile uses for some of the other materials that have been effective against both the eggs and larvae of the oriental fruit fly at comparatively low dosages in screening tests, but none of them have shown promise of being as generally useful as ethylene dibromide or 1-bromo-2-chloroethane.

**Table 4.—Summary of results with compounds screened against naked eggs and third-instar larvae of the oriental fruit fly.**

| Group of Compounds | Number | Number Killing 95% of Both Eggs and Larvae at 20 Mg. per Liter or Less | Number Found Useful in Treating Commodities |
|---|---|---|---|
| Halogenated | | | |
| Chlorides | 64 | 5 | 0 |
| Bromides | 63 | 6 | 2[1] |
| Iodides | 16 | 10 | 0 |
| Fluorides | 5 | 0 | 0 |
| Chlorobromides | 20 | 2 | 1[2] |
| Chlorofluorides | 9 | 0 | 0 |
| Nonhalogenated | 53 | 6 | 0 |
| Total | 230 | 29 | 3 |

[1] Methyl bromide and ethylene dibromide.
[2] 1-Bromo-2-chloroethane.

SUMMARY.—One hundred and eighty-nine compounds were screened as fumigants against naked eggs and third-instar larvae of the oriental fruit fly, *Dacus dorsalis* Hendel. The following compounds killed 95 per cent of both eggs and larvae at dosages of 10 to 50 mg. per liter: α-bromotoluene, α-chloroxylene, bromocy-

clopentane, chlorocyclopentane, 1-bromo-3-chlorobutane, 1-bromo-3-chloropropane, 2-bromo-1-chloropropane, 1-iodo-2-methylpropane, 2-iodobutane, 1-iodo-3-methylbutane, crotonaldehyde, and butylamine. The most promising materials, those killing 95 per cent of both eggs and larvae at less than 10 mg. per liter, were 1-chloro-4-iodobutane, diiodomethane, 1-iodohexane, 1-iodoheptane, iodoethane, 3-iodopropene, iodocyclohexane, allyl ester of isothiocyanic acid, 1,4-dichloro-2-butene, epibromohydrin, and 1,2-dibromobutane. The iodides were the most toxic. None of the other materials were as toxic as ethylene dibromide.

## LITERATURE CITED

**Balock, J. W.** 1951. Ethylene dibromide for destroying fruit fly infestations in fruits and vegetables. Science **114**(2953): 122.

**Balock, J. W.,** and D. L. Lindgren. 1951. Toxicity of various compounds as fumigants to eggs and larvae of the oriental fruit fly. JOUR. ECON. ENT. **44**(5): 657–9.

**Ferguson, J.,** and H. Pirie. 1948. The toxicity of vapours to the grain weevil. Ann. Appl. Biol. **35**(4): 532–50.

**Roark, R. C.,** and R. T. Cotton. 1929. Tests of various aliphatic compounds as fumigants. U. S. Dept. Agr. Tech. Bul. **162**.

# A Study of the Filth Flies in New York City—1953

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Flies have been known to be associated with a formidable list of pathogenic organisms for a considerable number of years and relatively recently their possible role in the dispersion and transmission of poliomyelitis virus has come to light (Paul *et al.* 1941, Toomey *et al.* 1941, Sabin & Ward 1941, Trask & Paul 1943, Ward *et al.* 1945, Francis *et al.* 1948, Melnick 1949). As a result there has been an increased interest in investigating the nature of total fly populations of various communities and urban fly control has been stimulated.

Information on the potential arthropod disease vectors in New York City is very incomplete and fragmentary. As a result of this study this information is made more complete. Although this investigation was conducted in a limited area of the city, at 168th Street and Broadway, and the results, therefore, may not represent the city as a whole, it was first desired to learn the nature of the total filth fly population in this semi-business and residential area of the Borough of Manhattan by determining the abundance of each species throughout the fly season. This information would be of use in future studies and might be of considerable value in the advent of the intentional distribution of certain biological agents of disease. Second, it was felt a comparison between this fly population and that of Rockford, Illinois, where Melnick (1949) demonstrated a relationship between certain fly species and poliomyelitis, would be of interest. Third, new biological information concerning some of the species might be obtained.

DESCRIPTION OF THE STUDY AREA.—Adjacent to the trapping locale, at the corner of 168th Street and Broadway, on the west and south, are the 20 acres occupied by the Columbia Presbyterian Medical Center. In other directions lie apartment buildings. The first floor of many of these, particularly those on the north-south streets, are occupied by business concerns of which there are, within 4 blocks in each direction, no less than 19 fruit and vegetable markets, 3 florist shops, 19 restaurants, 9 restaurants and bars, 4 taverns, 11 meat and/or poultry markets, and 1 fish market.

Quaterman *et al.* (1949) found that in Savannah, Georgia, approximately 60 per cent of all garbage containers throughout the city were producing large numbers of flies in the soft accumulation of "garbage sludge" in the bottom of the cans or in the soil immediately under unservice-

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able cans. It is reported by the U. S. Department of Health, Education, and Welfare, U. S. Public Health Service (Anon. 1953), that in Charleston, West Virginia, and Phoenix, Arizona, garbage stored in containers is the major positive breeding source of domestic flies in these cities. It would appear that in the area of New York City studied such wastes are also the chief source of fly breeding due to the general lack of other breeding material, the density of the population producing this type of waste, and to the business concerns which add to the concentration of these wastes.

PROCEDURE.—In the evaluation of fly populations the chief purpose of traps is to measure the qualitative aspects of fly prevalence and not the quantitative aspects. Schoof (1952) reported that for this purpose a small fly trap (6.125 inches in diameter and 8.125 inches high) can be used instead of the much larger and cumbersome standard U. S. D. A. metal trap. Cylindrical rodent cages, 8 inches in diameter and 9 inches tall, made of 6/16-inch hardware cloth, standing on three 2-inch legs, and possessing a removable top and bottom, were converted into fly traps by lining them with screening and inserting a converted screen cone. Bait, with a small quantity of water, was placed in crystallization dishes under the traps.

After trying a number of different baits, early in May, it became evident that raw fish and raw liver were the most attractive of those tested and these were therefore used throughout the rest of the trapping season. Two traps, one baited with fish and the other with liver, were placed in the courtyard between the Washington Heights Health Center, which houses the School of Public Health, and one of the other buildings of the Medical Center, 5 days a week, except for holidays and 3 stormy days. These two traps were placed about 12 yards apart. Two other traps were placed 14 yards apart on the roof of the Washington Heights Health Center (approximately 85 feet above street level) at the corner of 168th Street and Broadway. All traps were out 6 hours each day, from 9:15 A.M. to 3:15 P.M. The locations of the fish-baited traps were changed with the liver-baited traps on alternate days. The bait under each trap was changed once during each trapping week. Temperature readings were taken at 9:30 A.M., noon, and 3:15 P.M. on each trapping day and daily notations were made as to wind velocity, degree of sunlight and precipitation.

RESULTS.—An analysis of the fly population at 168th Street and Broadway, 1953, is given in table 1.

The largest number of flies taken in any one day and in any one trap were captured on August 26, when 450 were collected in a trap baited with fish on the ground. A total of 552 were taken for the day, only 24 at liver-baited traps. On August 19, 16 species were taken, 15 in one trap on the ground gaited with fish. The largest number of species were taken in September (23) and October (25). Fish always attracted more than liver.

The various species will be discussed in the order of their over-all frequency.

*Phaenicia sericata* (Meigen) was collected between May 6, the first day of trapping, and November 2. A total of 9,684 specimens were taken during this period and they represented 53.4 per cent of the total fly catch. This species was most common from July 1 to September 30. Power *et al.* (1943) report that *P. sericata* definitely preferred liver to fish in July and August at New Haven, Connecticut, in 1942. The converse was true here during 1953. About the first of July there was a change in food preference from liver to fish (Table 2), which occurred somewhat earlier for this species than for *P. pallescens*. During the time fish was preferred there were unexplained statistically significant variations among several of the 2-week periods in the percentage of flies attracted to this bait. There was a suggestion of a tendency, although quite insignificant, for *P. sericata* to switch back to a liver preference in the fall, however, the population decreased to zero before this trend progressed far. Only 9.1 per cent were trapped at an elevation of 85 feet. Bishopp & Laake (1921) found that *P. sericata* could fly 10.9 miles in less than 24 hours.

*Phormia regina* (Meigen) was collected between May 11 and Novenber 2. A total of 2,565 were trapped, which represented 14.2 per cent of the total catch. Although this species is said to be a cool weather species, being most common in the spring and fall, in these tests it was most common from June 16 to September

**Table 1.—Number of Filth Flies Trapped at 168th Street & Broadway, New York City, May 6–November 30, 1953.**

| SPECIES | MAY 6–31 | JUNE 1–15 | JUNE 16–30 | JULY 1–15 | JULY 16–31 | AUG. 1–15 | AUG. 16–31 | SEPT. 1–15 | SEPT. 16–30 | OCT. 1–15 | OCT. 16–31 | NOV. 1–15 | NOV. 16–30 | TOTAL TRAPPED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Phaenicia sericata* | 40(7)[1] | 156(28) | 270(42) | 769(56) | 2316(71) | 1100(66) | 2386(67) | 1430(59) | 772(58) | 341(25) | 98(8) | 5(5) | 1(1) | 9,684 |
| *Phormia regina* | 29(5) | 37(7) | 136(21) | 287(21) | 537(17) | 162(10) | 627(18) | 582(24) | 118(9) | 27(2) | 22(2) | 1(1) | 0 | 2,565 |
| *Cynomyopsis cadaverina* | 174(31) | 155(28) | 16(3) | 0 | 0 | 0 | 0 | 0 | 39(3) | 544(40) | 669(55) | 51(42) | 39(28) | 1,687 |
| *Calliphora vicina* | 43(8) | 32(6) | 29(5) | 22(2) | 24(1) | 30(2) | 37(1) | 57(2) | 180(14) | 242(18) | 233(20) | 36(30) | 76(54) | 1,041 |
| *Sarcophaga haemorrhoidalis* | 19(3) | 15(3) | 22(3) | 98(7) | 113(4) | 115(7) | 95(3) | 113(5) | 51(4) | 23(2) | 1 | 1(1) | 0 | 666 |
| *Sarcophaga* spp. | 13(3) | 9(2) | 5(1) | 19(1) | 52(2) | 60(4) | 103(3) | 83(3) | 52(4) | 35(3) | 15(1) | 0 | 0 | 446 |
| *Hylemya cilicrura*[2] | 150(27) | 71(13) | 48(8) | 31(2) | 19(1) | 43(3) | 29(1) | 11(1) | 10(1) | 8(1) | 7(1) | 0 | 2(1) | 429 |
| *Muscina stabulans* | 3(1) | 7(1) | 17(3) | 36(3) | 46(1) | 62(4) | 97(3) | 24(1) | 20(2) | 14(1) | 5 | 0 | 0 | 331 |
| *Phaenicia pallescens* | 10(2) | 33(6) | 57(9) | 21(2) | 17(1) | 9(1) | 27(1) | 26(1) | 30(2) | 25(2) | 12(1) | 0 | 0 | 267 |
| *Lucilia illustris* | 2(0) | 3(1) | 20(3) | 23(2) | 43(1) | 26(2) | 44(1) | 29(1) | 6 | 0 | 0 | 0 | 0 | 196 |
| *Ophyra leucostoma* | 7(1) | 0 | 2 | 24(2) | 37(1) | 17(1) | 28(1) | 10 | 0 | 4 | 8(1) | 0 | 0 | 137 |
| *Muscina assimilis* | 1(0) | 6(1) | 3(1) | 16(1) | 30(1) | 17(1) | 16(1) | 14(1) | 4 | 2 | 6(1) | 1(1) | 0 | 116 |
| *Hydrotaea* sp. | 0 | 0 | 0 | 2 | 2 | 6 | 8 | 7 | 13(1) | 37(3) | 40(3) | 3(3) | 0 | 118 |
| *Euzenia notata*[2] | 37(7) | 3(1) | 3(1) | 8(1) | 8 | 5 | 31(1) | 5 | 4 | 3 | 2 | 0 | 0 | 109 |
| *Scopeuma furcata*[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 39(3) | 16(13) | 20(14) | 83 |
| *Calliphora terrae-novae*[2] | 16(3) | 11(2) | 3(1) | 1 | 5 | 0 | 0 | 0 | 2 | 3 | 2 | 2(2) | 0 | 45 |
| *Calliphora vomitoria* | 7(1) | 12(2) | 1 | 3 | 2 | 0 | 2 | 0 | 0 | 4 | 7(1) | 2(2) | 3(2) | 43 |
| *Phaenicia caeruleiviridis* | 0 | 0 | 4(1) | 4 | 6 | 6 | 7 | 5 | 3 | 3 | 1 | 1(1) | 0 | 40 |
| *Scopeuma stercoraria*[2] | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 13(1) | 8(1) | 4 | 1(1) | 0 | 29 |
| *Lonchaea* sp.[2] | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 11(1) | 7(1) | 4 | 0 | 0 | 28 |
| *Hylemya* sp. 4[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6(1) | 0 | 1(1) | 12 |
| *Caritroga macellaria* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 8 |
| *Musca domestica* | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 8 |
| *Fannia canicularis* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 3 | 0 | 0 | 0 | 7 |
| Unidentifiable | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 |
| *Phaonia* sp.[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 |
| *Fannia manicata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2(2) | 0 | 3 |
| *Hylemya* sp. 2[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 |
| *Myospila medatabunda*[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| *Calobata antennipes*[2] | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Hoplodictya* sp.[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| *Hylemya* sp. 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Paregle radicum* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Pegomya* sp. 1[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Pegomya* sp. 2[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| *Poecilographus* sp.[2] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| *Stomoxys calcitrans* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 551 | 552 | 638 | 1366 | 3264 | 1659 | 3547 | 2407 | 1336 | 1347 | 1187 | 122 | 142 | 18,118 |
| Number of trapping days | 18 | 10 | 11 | 11 | 11 | 9 | 11 | 10 | 11 | 11 | 11 | 10 | 10 | |

[1] Per cent of total number trapped (to closest whole number) shown in parentheses.
[2] Sample specimens identified by Dr. C. H. Curran.

15. Prior to August 16 about 10 per cent of this species were taken in traps baited with liver. From August 16 until November 2 less than 1.5 per cent were in liver-baited traps, demonstrating an increase in the attractiveness of fish for this species during this time. Ground traps caught 84.7 per cent. Yates & Lindquist (1952) captured tagged adults 16.5 miles from a release point in 48 hours. One fly was taken in a trap 28 miles from the release point, which is the longest flight record for this species.

*Cynomyopsis cadaverina* (Robineau-Desvoidy) was collected from May 6 to June 30 and from September 28 to November 20. In all, 1,687 were trapped, representing 9.3 per cent of the total catch. Trapping did not begin early enough in the spring to determine the spring peak. The fall peak was reached during the last half of October. Of the spring catch 59 per cent were attracted to fish, while in the fall 60 per cent were taken at fish-baited traps. The traps on the roof captured 18.6 per cent of these flies. This species is considered a slow flying one.

*Calliphora vicina* Robineau-Desvoidy was trapped from May 7 to November 20, during which time 1,041 were captured, which represented 5.7 per cent of the total fly catch. Only 27 per cent were taken before mid-September, possibly because trapping did not begin early enough to determine a spring peak, the other 73 per cent being taken between September 16 and November 16. Fish attracted 64.5 per cent. At the 85 foot level 16.3 per cent

**Table 2.—Bi-weekly preference of three closely related fly species for liver and fish. 1953.**

| Period | Average Temp. °C. | *Phaenicia pallacens* (257)[1] | | | *Phaenicia sericata* (9,644)[1] | | | *Lucilia illustris* (194)[1] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Number | Number and Per Cent Attracted to Liver | Number and Per Cent Attracted to Fish | Total Number | Number and Per Cent Attracted to Liver | Number and Per Cent Attracted to Fish | Total Number | Number and Per Cent Attracted to Liver | Number and Per Cent Attracted to Fish |
| 6/ 1–15 | 25.6 | 33 | 25 (75.8)[2] | 8 (24.2) | 156 | 116 (74.4) | 40 (25.6) | 3 | 3 (100.0) | 0 (0.0) |
| 6/16–30 | 29.2 | 57 | 41 (72.0) | 16 (28.0) | 270 | 153 (56.7) | 117 (43.3) | 20 | 10 (50.0) | 10 (50.0) |
| 7/ 1–15 | 28.3 | 21 | 14 (66.6) | 7 (33.3) | 769 | 257 (33.4) | 512 (66.6) | 23 | 10 (43.5) | 13 (56.6) |
| 7/16–31 | 30.5 | 17 | 8 (47.0) | 9 (53.0) | 2316 | 1004 (43.4) | 1312 (56.6) | 43 | 15 (35.0) | 28 (65.0) |
| 8/ 1–15 | 27.8 | 9 | 2 (22.2) | 7 (77.8) | 1100 | 505 (46.0) | 595 (54.0) | 26 | 8 (30.8) | 18 (69.2) |
| 8/16–31 | 31.2 | 27 | 11 (40.7) | 16 (59.3) | 2386 | 600 (25.2) | 1786 (74.8) | 44 | 8 (18.1) | 36 (81.9) |
| 9/ 1–15 | 26.7 | 26 | 0 (0.0) | 26 (100.0) | 1430 | 387 (27.0) | 1043 (73.0) | 29 | 5 (17.5) | 24 (82.5) |
| 9/16–30 | 22.1 | 30 | 4 (13.3) | 26 (86.7) | 772 | 154 (20.0) | 618 (80.0) | 6 | 0 (0.0) | 6 (100.0) |
| 10/ 1–15 | 17.8 | 25 | 22 (88.0) | 3 (12.0) | 341 | 117 (34.6) | 224 (65.4) | | | |
| 10/16–31 | 18.2 | 12 | 7 (58.4) | 5 (41.6) | 98 | 46 (47.0) | 52 (53.0) | | | |
| 11/ 1–15 | 10.5 | 0 | 0 (0.0) | 0 (0.0) | 5 | 3 (60.0) | 2 (40.0) | | | |
| 11/16–30 | 14.4 | 0 | 0 (0.0) | 0 (0.0) | 1 | 0 (0.0) | 1 (100.0) | | | |

[1] These figures differ from the totals in table 1 since May is not included because several baits were being tested during that time.
[2] Numbers in parentheses represent per cent of total of each species collected.

were captured. This species is also considered a slow flying one.

*Sarcophaga haemorrhoidalis* (Fallén), which was captured between May 11 and November 2, was most abundant in July, August and September. The 666 trapped specimens represented 3.7 per cent of the total number of flies captured. Fish-baited traps caught 80 per cent. The percentage taken on the roof was the third highest of all species, 43.3 per cent.

*Sarcophaga* spp., of which there were thought to be five, other than *S. haemorrhoidalis*, represented 2.7 per cent of the total number of flies trapped, and numbered 446. They were most common during August and September. Fish attracted 84.4 per cent of this group. The traps on the roof caught 24 per cent of these several species.

*Hylemya cilicrura* Rondani made up 2.4 per cent of the total fly catch, with 429 being taken in the traps. Liver attracted 51.5 per cent and fish 48.5 per cent. This is one of the few species, caught in any numbers, which was taken as frequently in liver-baited traps as in fish-baited traps. The traps on the roof caught 14.4 per cent. This was the only one of four species of *Hylemya* captured which was common in the spring and early summer, although taken between May 6 and November 18. The other three species were taken only in the fall of the year.

*Muscina stabulans* (Fallén) composed 1.3 per cent of the total catch with 331 flies trapped. This fly was most prevalent during the midsummer but was taken from May 11 to October 20. Fish attracted 90.3 per cent. Only 4.3 per cent were taken at the 85 foot level, which is the third smallest percentage taken at this level of all the fly species caught, and is in marked contrast to *M. assimilis* which was the species having the second highest percentage trapped on the roof.

*Phaenicia pallescens* (Shannon) represented 1.4 per cent of the total catch with 267 specimens taken. Although it was captured from May 14 to October 15, it appeared to be most numerous in June and the first half of July. Table 2 indicates the change in food preference throughout the season and compares it with two other closely related species. This is the only one of the three species which demonstrated a completely statistically significant switch from a liver preference in the spring and early summer to fish in midsummer and back to liver again in the fall. The change from a liver to a fish preference occurred somewhat later than it did for *P. sericata*. The traps on the roof of the building caught 11.4 per cent.

*Lucilia illustris* (Meigen) composed 1.0 per cent of the total number trapped, with 196 specimens taken. This species was collected from May 15 to September 29, with the population peak occurring between the middle of June and the middle of September. As indicated in table 2 no preference for liver over fish can be noted for this species in the early part of the season, the fish and liver preference being about the same. As the season advanced, more and more of a preference was shown for fish. However, due to the small numbers involved, the increase in preference for fish does not attain statistical significance until the middle of August. Only 3.7 per cent were taken on the roof, the second smallest percentage of all fly species. Bishopp & Laake (1921) tentatively fixed the flying range of this

species at 3.5 miles.

*Ophyra leucostoma* (Wiedmann) represented 0.75 per cent of all flies trapped, numbering 137. It was taken from May 23 to October 28. Fish-baited traps captured 94.6 per cent. The traps on the roof captured 24.6 per cent. Nearly 82 per cent of the 22 taken after September 1 were captured on the roof. Bishopp & Laake (1919) report capturing this species 7 miles from a release point.

*Muscina assimilis* (Fallén), of which 116 specimens were collected, represented 0.64 per cent of the total trapped population. This species was taken from May 19 to November 2. The peak of the population appeared to be reached during July and the first half of August. Fish attracted 93.9 per cent. The percentage taken at the 85 foot level was the second largest of all, 66 per cent, with only 34 per cent taken at ground level. This seems even more remarkable when it is compared to its closely related species, *M. stabulans*, which had the second lowest percentage collected on the roof of all species trapped, 4.3. This is evidence of a marked biological difference between these two allied species.

*Hydrotaea* sp., which Dr. Curran felt could not readily be identified to species, represented 0.65 per cent of the total catch with 118 specimens trapped. It was taken from July 3 to November 2. Fish attracted 94.8 per cent. At the 85 foot level 12.6 per cent were captured.

*Euexesta notata* Wiedmann, a member of the family Otitidae, was taken 109 times which represented 0.6 per cent of the total catch. It was trapped from May 11 to October 9, with the peak population occurring in May. A larger percentage of this species, 85 per cent, was taken on the roof than any other. Fish attracted 96 per cent.

*Scopeuma furcata* Say was definitely a fall species, unless trapping in the spring didn't begin early enough to catch them. They were taken between September 25 and November 23 with the peak population between the middle of October and November 23. The 83 specimens trapped represented 0.46 per cent of the total catch. More were taken in liver-baited traps, 58.5 per cent, than in fish-baited traps. The traps on the roof caught only 1.2 per cent, the lowest of all trapped species.

*Calliphora terrae-novae* Macquart made up 0.25 per cent of the total flies caught with 45 specimens taken. It is said by Hall (1948) to be most common in July and August. In these tests only 6 were taken in July and none in August. Over half were trapped in May and the first half of June. They were taken from May 11 to July 25 and from September 24 to November 2. Fish attracted 66.7 per cent. The traps on the roof caught 41.4 per cent.

*Calliphora vomitoria* (Linnaeus) which represented 0.24 per cent of the total number of flies collected was taken 43 times. September was the only month in which none was taken. It was collected first on May 11 and last on November 17. Fish attracted 89.2 per cent and 14 per cent were captured on the roof. This species is one of the slowest flying of the genus.

*Phaenicia caeruleiviridis* (Macquart) was trapped from June 18 to November 2. Forty specimens were taken, which represented 0.22 per cent of the total catch. They appeared to be more numerous in mid-summer. Eighty per cent were attracted to fish. Only 8 per cent were taken at the 85-foot level.

*Scopeuma stercoraria* Linnaeus, taken only 29 times, represented 0.16 per cent of all the flies trapped. Although a single specimen was taken on June 19 it was August 6 before the second was trapped. This species appears somewhat earlier than *S. furcata*. The largest number, 13, was taken during the last half of September and the last was captured on November 12. All the specimens were taken at ground level. Fish attracted 65 per cent, thus possibly differing from *S. furcata* of which only 41.5 per cent were attracted to fish.

*Lonchaea* Fallén, the type genus of the family Lonchaeidae, was represented by one species which Dr. C. H. Curran felt could not be determined with accuracy. It was collected 28 times and represented 0.15 per cent of the total catch. They were first collected on August 26 and last on October 30. Most were taken during the last half of September and the first half of October. Fish attracted 50 per cent and liver 50 per cent. The traps on the roof collected 52 per cent.

*Hylemya* sp. 4 was taken only between October 8 and November 18. The 12 specimens collected represented 0.06 per

cent of the total number of flies trapped. The traps on the roof caught nine, or 75 per cent, and fish likewise attracted 75 per cent of this species.

*Callitroga macellaria* (Fabricius), taken only between August 19 and September 9, was collected on eight different occasions. It represented 0.04 per cent of the total catch. All were caught in fish-baited traps and two, or 25 per cent, were taken on the roof and the other six at ground level. Bishopp & Laake (1921) found that adults would migrate as far as 8 miles in 24 hours and 10 miles in less than 48 hours; they observed a maximum migration of better than 15 miles.

*Musca domestica* Linnaeus was collected eight times during July, August, and September and represented 0.044 per cent of the total catch. All were taken at ground level, seven at fish and one at liver. This exceedingly low house fly catch coincides closely with the findings of Power *et al.* (1943) in New Haven and Hartford, Connecticut, Newark, New Jersey and Montreal, Canada. Activities carried on by the Communicable Disease Center (Anon. 1953) in Charleston, West Virginia, and Phoenix, Arizona, indicated that in Phoenix *M. domestica* was the fly found most commonly in various breeding media, while in Charleston it was sixth among the flies found in the same breeding media. Fly trap collections in these two towns correlated with the larval findings as far as *M. domestica* was concerned. Schoof *et al.* (1951) report that the house fly was the prevalent species during the peak months of fly production in Topeka, Kansas, while during the same period flies of the *Phaenicia* group predominated in Troy, New York. Although it is known that the house fly has bait preferences, it seems that it is actually less common in the eastern portion of the country than it is farther west.

Thirteen other species trapped are listed in table 1 along with the number of each and the period in which trapped.

DISCUSSION.—Hall (1948) points out that all samples of flies found positive for poliomyelitis virus through 1943 contained samples of *Phaenicia sericata* and *Phormia regina* as well as a few specimens of less abundant species. He further states. . . "these species are not frequent visitors to human excrement, especially that in outdoor deep-pit latrines. Where and how they originally obtained the virus is still an unsolved problem." Sabin & Ward (1941) write, "The ease with which poliomyelitis virus can thus be isolated from flies caught in urban areas (where immediate contamination with feces in open privies is at least not obvious) suggests that they may play an important role in transmission of the virus. . . ." Thus it appears that it may be possible for flies to become infected without coming in direct contact with infected human feces.

According to Frant[2] the year 1953 was one of low poliomyelitis incidence in New York City, presumably because of the low number of non-immunes. However, it is of interest that with one exception (Table 3, September 2–15, *P. regina*) the percentage of the total fly population represented by *Phaenicia sericata, Phormia regina, Sarcophaga* spp. and *Cynomyopsis cadavarina* at the area of this study in New York City was considerably greater than that found by Melnick (1949) in Rockford, Illinois, during the time he found these same species positive for the virus of poliomyelitis. It further would seem probable that these percentages were greater in New York City than in Rockford throughout most of the breeding season. If it is not necessary for flies to come in contact with polio-contaminated feces and if they are of any importance in the transmission of the disease, it is evident that the proper species are common enough percentagewise in this area of New York City at least during some years, to be a factor in its dissemination when there are large numbers of non-immunes, providing that the total numbers of these flies are sufficiently large.

The change in preference by *Phaenicia sericata* and *P. pallescens* from liver to fish is of interest. Power *et al.* (1943) found liver to be preferred to fish by *P. sericata* in July and August in New Haven, Connecticut, in 1942, however, they were using four baits, raw liver, fish, dog feces, and banana with sugar. Traps baited with these materials were set 5 yards apart. It may be possible that either or both the additional baits drew more flies away from the fish than from the liver. The relative location of these additional baits may have played an important factor in determining this. The use of several baits may also

[2] Personal communication from Dr. S. Frant, First Deputy Commissioner of Health, New York City Department of Health.

**Table 3.—A comparison, of the per cent of the total fly population represented by each of several species at Rockford, Illinois, 1947, and at 168th Street and Broadway, New York City, 1953.**

| Fly Species | Aug. 20–Sept. 1 | | Sept. 2–15 | | Sept. 16–29 | | Sept. 30–Oct. 10 | |
|---|---|---|---|---|---|---|---|---|
| | Rockford[1] | N.Y.C. | Rockford[1] | N.Y.C. | Rockford[1] | N.Y.C. | Rockford[1] | N.Y.C. |
| *Phaenicia sericata* | 24.5[2] | 62.2 | 23.6 | 68.1 | 21.4 | 58.3 | 20.9 | 40.7 |
| *Phormia regina* | 22.0[2] | 25.2 | 24.5[2] | 12.9 | 20.1 | 9.5 | 22.8 | 1.9 |
| *Ophyra* sp. | 17.5 | 0.5 | 20.1 | 0.4 | 19.0 | 0.0 | 4.2 | 0.1 |
| *Musca domestica* | 6.1 | 0.0 | 2.9[2] | 0.1 | 2.1 | 0.0 | 1.0 | 0.0 |
| *Fannia* spp. | 5.9 | 0.2 | 5.0 | 0.9 | 5.4 | 0.8 | 4.0 | 1.0 |
| *Muscina stabulans* | 5.6 | 1.8 | 3.1 | 1.1 | 2.6 | 1.5 | 1.5 | 1.5 |
| *Muscina assimilis* | 3.0 | 0.2 | 1.8 | 0.7 | 1.5 | 0.3 | 1.3 | 0.1 |
| *Sarcophaga* spp. | 3.4 | 5.3 | 3.6[2] | 9.2 | 2.5 | 8.0 | 2.4 | 6.2 |
| *Phaenicia caeruleiviridis* | 2.6 | 0.1 | 3.5 | 0.3 | 3.8 | 0.2 | 1.6 | 0.1 |
| *Lucilia illustris* | 2.0 | 1.1 | 2.8 | 1.3 | 3.0 | 0.4 | 3.8 | 0.1 |
| *Calliphora vicina* | 1.7 | 0.6 | 3.3 | 2.9 | 5.9 | 13.7 | 12.6 | 17.0 |
| *Cynomyopsis cadaverina* | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.2 | 10.5[2] | 23.5 |

[1] Fish plus ripe fruit used as bait.
[2] Found positive by Melnick (1949) for poliomyelitis virus.

explain why liver nearly always attracted more flies of all species than fish in the New Haven study, which was just the opposite from what was found during the course of this investigation. The fact that *P. pallascens* demonstrated two complete significant changes in preference between liver and fish and that *P. sericata* demonstrated one, with a slight insignificant indication of a trend toward the other, again demonstrates that the attractiveness of certain substances may vary for the same fly species during any given season.

Three species were taken more than 50 per cent of the time at an elevation of approximately 85 feet. Of 109 *Euxesta notata*, 85 per cent were taken at this elevation, 66 per cent of 116 *Muscina assimilis* and 75 per cent of 12 *Hylemya* sp. 4. The percentage of the first two species is significant. Three species were taken more commonly in liver-baited traps, none, however, indicated a significant preference for liver. Of 83 *Scopeuma furcata*, 58.5 per cent were attracted by liver, 51.5 per cent of 429 *Hylemya cilicrura*, and of 38 *Lonchaea* sp. 50 per cent were taken in liver-baited traps.

Summary.—The nature of the total population of flies, which are attracted to animal waste for feeding or breeding purposes, in the semi-business and residential area around 168th Street and Broadway, New York City, was determined for the year 1953 (Table 1).

Two species, *Euxesta notata* and *Muscina assimilis*, were trapped significantly more frequently at an 85-foot level than at ground level.

It was shown that *Phaenicia pallascens* and *P. sericata* demonstrated certain significant changes in preference between liver and fish (Table 2).

In most instances of the fly species that Melnick (1949) found positive for poliomyelitis virus in Rockford, Illinois, the percentage of such species was far greater in the area of this study in 1953, during the same season of the year (Table 3).

## Literature Cited

**Anonymous.** 1953. Communicable Disease Center 1951–1952 activities. Public Health Service Pub. No. 302.

**Bishopp, F. C.,** and E. W. Laake. 1919. The dispersion of flies by flight. Jour. Econ. Ent. 12: 210–1.

**Bishopp, F. C.,** and E. W. Laake. 1921. Dispersion of flies by flight. Jour. Agr. Res. 21: 729–66.

**Francis, T., Jr.,** G. C. Brown, and L. R. Penner. 1948. Search for extra-human sources of poliomyelitis virus. Jour. Amer. Med. Assoc. 136: 1088–92.

**Hall, D. G.** 1948. The blowflies of North America. The Thomas Say Foundation.

**Melnick, J. L.** 1949. Isolation of poliomyelitis virus from single species of flies during an urban epidemic. Amer. Jour. Hyg. 49: 8–16.

**Paul, J. R.,** J. D. Trask, M. B. Bishop, J. L. Melnick, and A. E. Casey. 1941. The detection of poliomyelitis virus in flies. Science 94: 395–6.

**Power, M. E.,** J. L. Melnick, and M. B. Bishop. 1943. A study of the 1942 fly population of New Haven. Yale Jour. Biol. and Med. 15: 973–5.

**Quarterman, K. D.,** W. C. Baker, and J. A. Jensen. 1949. The importance of sanitation in municipal fly control. Amer. Jour. Trop. Med. **29:** 973–82.

**Sabin, A. B.,** and R. Ward. 1942. Flies as carriers of poliomyelitis virus in urban epidemics. Science **94:** 590–1.

**Schoof, H. F.** 1952. The attached bait pan fly trap. JOUR. ECON. ENT. **45:** 735–6.

**Schoof, H. F.,** R. E. Siverly, and J. H. Coffey. 1951. Dieldrin as a chemical control material on community fly control programs. JOUR. ECON. ENT. **44:** 803–7.

**Toomey, J. A.,** W. S. Takacs, and L. A. Tischer. 1941. Poliomyelitis virus from flies. Proc. Soc. Exp. Biol. and Med., **48:** 637–9.

**Trask, J. D.,** and J. R. Paul. 1943. The detection of poliomyelitis virus in flies collected during epidemics of poliomyelitis. I. Methods, results and types of flies involved. Jour. Exp. Med. **77:** 545–56.

**Ward, R.,** J. L. Melnick, and D. M. Horstman. 1945. Poliomyelitis virus in fly-contaminated food collected at an epidemic. Science **101:** 491–3.

**Yates, W. W.,** and A. W. Lindquist. 1952. Further studies of dispersion of flies tagged with radioactive phosphoric acid. JOUR. ECON. ENT. **45:** 547–8.

# Studies on *Apsylla cistellata* Buckton causing Mango Galls in India

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The mango galls caused by *Apsylla cistellata* Buckton, are responsible for extensive losses to the mango crop in the Tarai districts every year. The disease has so far been reported from Dehra Dun (Buckton 1893), Gorakhpur (Lal 1950), and recently from Pilibhit (Lal 1951) districts of Uttar Pradesh. It also occurs in some of the districts of Bihar and Bengal (Crawford 1912, 1914). It is very likely that a survey may reveal its presence in nearly all the Tarai districts, where there is extensive mango cultivation.

Since the insects are inside the galls, no external applications of insecticides were made to test the effectiveness of such control measures. Mathur (1935, 1946) worked out the biology of the insect, but the oviposition period, longevity of the adults and the time of egg hatching were not known, therefore it was necessary to study the biology in more detail and also test the efficacy of some of the recently available insecticides.

DESCRIPTION OF INJURY.—The present study showed that the buds are changed into hard conical galls, inside of which the psyllid nymphs develop into adults. Due to irritation caused by the feeding of the nymphs, the bud develops scaly leaves which imbricate the central axis and form the gall. The nymphs numbering up to 16 in a gall, are attached to the purplish central axis. They suck the sap and exude whitish sticky droplets through their anal openings. The size of the full grown gall varies from 0.75 to 1.5 inches in length and 0.5 to 0.75 inch in its maximum diameter. The colour is green to pale green. The galls dry out after opening and the scales drop. In case the attack is severe, the affected twig may also die. Due to the transformation of the reproductive and vegetative buds into galls, practically no fruit is set. The disease is most severe and common on the grafted varieties, while the mango saplings escape the damage in the Dun valley.

BIOLOGY.—By the last week of March, the insects inside the galls are in the adult stage. The galls open due to the elongation of the central axis and provide exits for the adults. The insects pair and deposit the eggs primarily in the mid-ribs, sometimes in the ribs also, of the new leaves. The eggs are partly embedded and white in colour. The points where eggs are inserted are first brown and later change to black, while the egg-laid region changes from pale green to olive green. As many as 150 eggs may be laid by a single female in a length of about 4 inches. Oviposition finishes by the last week of April, after which no adults are noticed.

Under laboratory conditions the life of the adult, ranged from a few minutes to 36 hours. The eggs hatch out by the third week of September and the nymphs burst open the tissues and crawl over to the adjacent buds, which they enter and change into galls. The first-stage nymph is not provided with wing pads and in the second stage there are prominences only.

The wing pads become quite prominent in the following three stages. Females are larger than males and the sex ratio is 1:1. There is only one generation in a year at Dehra Dun.

Mathur (1935, 1946) observed that the nymphs remain inside the galls throughout the winter. The galls begin to open in March and dehiscence continues till mid-April. Soon after emergence from the galls, the psyllids pair and deposit the eggs in the mid-ribs of the new leaves. Preliminary control trials were therefore carried out to attack the nymphs, adults, and eggs with various insecticides.

INSECTICIDE TESTS.—The trees were sprayed at fortnightly intervals, beginning the middle of February and continuing to the first week of May with the following insecticides:—

DDT, 0.25%
DDT 0.5%
Toxaphene W. P. 25%–0.1% (1 lb. to 25 gallons of water).
BHC 3.75% (12 ozs. of 50% to 1 gallon of water).
Tar-oil, miscible wash, 3%[1]
Crude oil emulsion, 3%

Trees sprayed with tar-oil wash, 3.75 per cent BHC, and 3 per cent crude oil emulsion showed a reduction of 98.5, 85, and 75 per cent, respectively, in the formation of galls. Since it was thought to be more convenient to control the disease by destroying the eggs, a tree heavily galled and having sufficient eggs laid in the leaves was sprayed with 3 per cent tar-oil wash during September before the hatching of the eggs and a similar tree was left untreated. On the treated tree there was an 80 per cent reduction in galls whereas the untreated check showed an increase of 14.5 per cent.

[1] *Oxicide*, I.C.I. product.

## LITERATURE CITED


**Buckton, G. B.** 1893. *Psylla cistellata* damaging mango trees at Dehra Dun. Ind. Mus. Notes III, pp. 91–92.

**Lal, K. B.** 1950. Gall Makers on Mango Leaves and shoots, Summary of the Annual Report for the period July 1, 1949 to June 1950 of the Scheme for controlling some serious Insect Pests attacking fruits and fruit trees grown in the plains of the Uttar Pradesh, India, p. 4.

**Lal, K. B.** 1951. Gall Makers on Mango Leaves and shoots, Summary of the Annual Report for the period July 1, 1950 to June 1951 of the Scheme for controlling some serious Insect Pests attacking fruits and fruit trees grown in the plains of the Uttar Pradesh, India, p. 4.

**Crawford, D. L.** 1912. *Psylla cistellata* from Galls on Mango Shoots, Dehra Dun, Rec. Ind. Mus. No. 7, pp. 421–22 and p. 429.

**Crawford, D. L.** 1914. *Psylla cistellata* from Galls on Mango trees, U. S. Nat. Mus. Bul. 85.

**Mathur, R. N.** 1935. On the Biology of the Psyllidae (Homopt.). Indian For. Rec. 1(2): 38–9.

**Mathur, R. N.** 1946. On the immature stages of some Psyllidae. Indian Jour. Ent. 8(pt. 2): 224–6.


# Effectiveness of DDT for Cabbage Caterpillar Control in Western New York: 1944 and 1953[1]

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When DDT became available, it proved to be highly effective against cabbageworms. Since it was more effective and cheaper than rotenone and lead arsenate, it replaced them for cabbageworm control. McEwen & Chapman (1952) reported that the imported cabbageworm, *Pieris rapae* (L.), had developed a high degree of DDT resistance in a Wisconsin area. In the same year, growers of market cabbage on Long Island also had difficulty in controlling cabbageworms with DDT. In western New York, in the years from 1944 to 1952, DDT dusts were used in experimental plots. During this time the effectiveness of DDT steadily declined (Table 1), and it was necessary to gradually increase the concentration used to 3 to 5 per cent, whereas in the first years of its use 1 to 2 per cent dusts were adequate. In view of these facts, a re-evaluation of the effectiveness of DDT for cabbageworm control in western New York was undertaken in 1953. The two species involved are the imported cabbageworm and the cabbage looper, *Trichoplusia ni* (Hbn.). The results of this re-evaluation are herein reported and compared with

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**Table 1.—Effectiveness of DDT dusts for cabbageworm control, 1944–1953, as determined by injury-index evaluations. Geneva, N. Y.**

| YEAR | NUMBER APPLICATIONS | PER CENT DUST | PER CENT CONTROL |
|---|---|---|---|
| 1944 | 3 | 0.5 | 93 |
| | | 1.0 | 96 |
| | | 2.0 | 96 |
| 1945 | 3 | 1.0 | 89 |
| 1946 | 3 | 2.0 | 78 |
| 1947 | 2 | 2.0 | 84 |
| | | 4.0 | 94 |
| 1948 | 3 | 0.5 | 56 |
| | | 1.0 | 54 |
| | | 2.0 | 68 |
| | | 4.0 | 84 |
| 1949 | 3 | 2.0 | 90 |
| | | 4.0 | 95 |
| 1951 | 3 | 5.0 | 87 |
| 1952 | 4 | 5.0 | 63 |
| 1953 | 4 | 0.5 | 18 |
| | | 1.0 | 44 |
| | | 2.0 | 73 |
| | | 4.0 | 52 |
| | | 8.0 | 73 |

the control obtained in 1944.

METHODS.—A series of dusts of varying concentrations was applied at 35 pounds per acre with a rotary-type hand duster. In all experiments, plots were replicated four times in a randomized block design. Records were taken by two methods. One method was by the use of a feeding-injury index as described by Hervey (1943). This was the method used for the results presented in table 1. The other method was that of counting the number of caterpillars present. This was done to obtain information on the abundance and control of each of the two species. Where the plants were large, it was necessary to cut them up in order to make the counts. Where the plants were small, i.e., had not yet formed heads, it was not necessary to cut them up to make the counts. Three such experiments were made in 1953 and are designated 1953a, 1953b, and 1953c.

RESULTS.—In 1944, a series of plots was treated with three applications of 0.5, 1 and 2 per cent DDT dusts. Records taken by the feeding-injury index method showed a control value of 93 per cent for the 0.5 per cent dust and 96 per cent for the 1 and 2 per cent dusts. A similar test was conducted in 1953. It differed from the 1944 test in also including 4 and 8 per cent dusts, and in that four applications were made instead of three. In 1953, the 8 per cent DDT dust gave poorer control than did the 0.5 per cent dust in 1944. The feeding injury in plots receiving four applications of 0.5 per cent dust in 1953 was so severe that, in general appearance, these plots could not be distinguished from the untreated plots. The results of these 1944 and 1953 tests are included in table 1. In this same series, four spray applications of 0.5 pound DDT per acre gave 70 per cent control, whereas four spray applications of 0.5 pound endrin gave 93 per cent control.

Another test was conducted in 1944, using 0.5, 1 and 2 per cent DDT dusts and also 0.25, 0.5 and 1 per cent rotenone dusts applied at 35 pounds per acre. Only one application of the insecticides was made. The control obtained with the DDT dusts is given in table 2. Records were obtained by making counts of the caterpillars present on the plant 2 days after the insecticides were applied. The cabbage was just beginning to head at this time. The rotenone dusts gave much poorer control

**Table 2.—Effectiveness of DDT dusts for cabbageworm control in several fields in western New York: 1944 and 1953.[1]**

| DDT CONC. | 1944 | | 1953a | | 1935b | | 1953c |
|---|---|---|---|---|---|---|---|
| | Worm[2] | Looper | Worm | Looper | Worm | Looper | Looper |
| 0.5% | 92.8 | 93.1 | 44.6 | 00.0 | 90.1 | 21.8 | 38.4 |
| 1.0 | 96.6 | 95.3 | 65.7 | 65.3 | 95.0 | 57.4 | 66.1 |
| 2.0 | 99.6 | 99.4 | 76.5 | 83.1 | 98.0 | 78.3 | 59.8 |
| 4.0 | — | — | 89.4 | 79.3 | 99.0 | 61.2 | — |
| 6.0 | — | — | — | — | — | — | 77.1 |
| 8.0 | — | — | 90.1 | 94.4 | 100.0 | 76.0 | 75.9 |
| Check[3] | 6.6 | 4.7 | 0.6 | 0.3 | 4.1 | 5.4 | 20.4 |

[1] Results in 1944 and 1953a are directly comparable but other combinations are not.
[2] Imported cabbageworm.
[3] Number of caterpillars per plant in untreated plots.

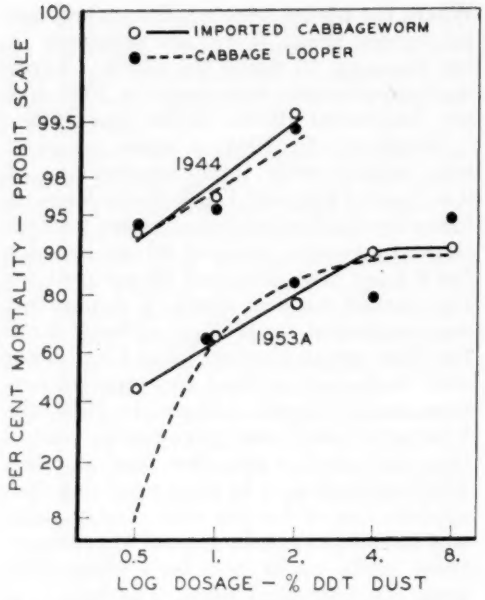


FIG. 1.—Control of imported cabbageworm and cabbage looper with DDT dusts in 1944 and 1953.

of the cabbage looper than of the imported cabbageworm. This agrees with the results obtained by Huckett (1936, 1940). There was no difference between the two species in the control obtained with DDT.

*Experiment 1953a.*—In 1953, a test similar to the foregoing was conducted including higher DDT concentrations but no rotenone dusts. This test was carried out at the same time of the season, the plants were about the same size and the method of taking records was the same. Each plot consisted of four rows 30 feet long and records were taken from the center two rows. This experiment should then be considered comparable to that of 1944. The control obtained in this test, against either species, was much poorer than that obtained in 1944 (Table 2 and Fig. 1), even though the infestation was lower in 1953. The curve in figure 1 indicating cabbage looper control is drawn only for purposes of illustrating the differences between control of this insect in 1944 and 1953, and an attempt to derive further information from it would be unjustifiable. The line in figure 1 for imported cabbageworm control shows considerable linearity except for the results obtained with the 8 per cent dust.

*Experiment 1953b.*—Each plot consisted of four rows 50 feet long. DDT applications were made on July 24, August 12, August 21, and September 2. A schedule such as this would approximate the schedule an efficient grower would follow. Insect counts were made on September 7 and 8. Since the plants were large and the heads well-developed, it was necessary to cut up the plants to obtain accurate counts of the caterpillars present. Six plants were taken from each plot. Evaluations based on feeding injury were also made. These have been referred to previously and are presented in table 1.

The control of the imported cabbageworm was much better than the control of the cabbage looper (Table 2 and Fig. 2). The 1, 2 and 4 per cent dusts all gave at least 95 per cent control of the imported cabbageworm, and none were found in the plots treated with the 8 per cent dust. The regression of mortality on dosage was calculated for the results obtained with the imported cabbageworm in this test (Fig. 2). A test of linearity (Snedecor 1946, p. 122) applied to this regression gave a value significant at odds greater than 99:1 thus indicating that no factor, such as DDT resistance, was operating to such an extent as to disturb the expected linearity of the transformed data.

No linear relationship between the converted dosage-mortality values was apparent in the case of the cabbage looper.

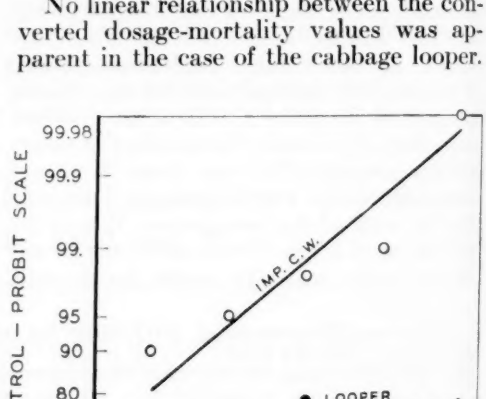


FIG. 2.—Control of imported cabbageworm (imp. c.w.) and cabbage looper with four applications of DDT dusts in 1953.

Once 60 to 80 per cent mortality was reached, there was little evidence of control increasing with dosage. In view of the difference in control between the two species, the poor overall control obtained with DDT in these plots, as indicated by the feeding-injury evaluations (Table 1, 1953), appears to be due to the cabbage looper. This conclusion is supported by the fact that the number of larvae of the two species was almost the same in the untreated plots. A single application of DDT, in Experiment 1953a, resulted in poor control of the imported cabbageworm, whereas excellent control was obtained on a seasonal basis with four applications. This may indicate that these insects, although having some decrease in susceptibility to DDT, could not tolerate the cumulative effect of more than one application.

*Experiment 1953c.*—The field in which this test was carried out had, according to the grower, received two applications of 3 per cent DDT dust applied at 35 pounds per acre. The experimental series was applied after the field had received these two applications. A large number of caterpillars, mostly loopers, were present. Each plot consisted of one row 30 feet long, separated from other plots by three untreated rows. For sampling, three plants were taken from each plot. Counts were made on September 15, 4 days after dusting.

The results obtained with the cabbage looper are presented in table 2. The imported cabbageworms surviving in the treated plots were mostly well into the head, and it is doubtful that these larvae had come in contact with the DDT. Therefore, the results obtained with this species are not presented. The cabbage looper population was very high, about 20 per head, and the control obtained was not good. Although a few loopers may have escaped contact with the DDT, there were too many remaining in all the DDT-treated plots to be accounted for in this way. This experiment indicates, as does Experiment 1953b, that DDT is no longer effective against this insect.

SUMMARY.—Data are presented showing the degree of control of the imported cabbageworm and the cabbage looper obtained with DDT dusts in 1944 and 1953. Also shown is the manner in which the effectiveness of DDT has steadily decreased since 1944 until in 1953 it has reached a level where its future adequacy for cabbageworm control in western New York is doubtful. This poor control cannot be attributed to seasonal or area variation since the trend for decreasing effectiveness of DDT was quite consistent. Furthermore, when DDT first became available, it was highly effective against cabbage caterpillars in widely separated areas (Apple 1945, Dills & Odland 1948, Huckett 1946, 1949).

The imported cabbageworm was not as susceptible to DDT in 1953 as in 1944, but there is no evidence for assuming that it is at present DDT-resistant in western New York. The cabbage looper appears to have acquired a considerable degree of DDT resistance. It was responsible for the failure of DDT to give good control when applied in a four-application schedule in 1953.

## LITERATURE CITED

Apple, J. W. 1945. DDT to control cabbage caterpillars. JOUR. ECON. ENT. **38**: 410–1.

Dills, L. E., and M. L. Odland. 1948. Cabbage caterpillar insecticide tests. JOUR. ECON. ENT. **41**: 948–50.

Hervey, G. E. R. 1943. A study of rotenone-bearing dusts for cabbage insect control. N. Y. State Agr. Expt. Sta. Bul. **703**: 39–44.

Huckett, H. C. 1936. Some tests of pyrethrum, derris and nicotine mixtures against cabbage worms. JOUR. ECON. ENT. **29**: 575–80.

Huckett, H. C. 1940. Non-arsenical dusts for cauliflower and cabbage worm control on Long Island. N. Y. State Agr. Expt. Sta. Bul. **695**.

Huckett, H. C. 1946. DDT and other new insecticides for control of cauliflower worms on Long Island JOUR. ECON. ENT. **39**: 184–8.

Huckett, H. C. 1949. DDT sprays and dusts for control of cauliflower and cabbage caterpillars on Long Island. Cornell Agr. Expt. Sta. Bul. **852**.

McEwen, F. L., and R. K. Chapman. 1952. Imported cabbageworm resistance to insecticides. JOUR. ECON. ENT. **45**: 717–22.

Snedecor, G. W. 1946. Statistical methods. 4th Edition. Iowa State College Press, Ames, Iowa.

# Dispersion to the Tropics of the Spirea Aphid

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The first recorded occurrence of the spirea aphid, *Aphis spiraecola* Patch, was on bridal wreath, *Spiraea prunifolia*, on the campus of the Agricultural College at Fort Collins, Colorado in 1907 (Gillette 1910). It was not noted at this locality subsequently by Prof. Gillette however, but on a collection trip in June 1909, he found it at Washington, D. C., at three localities in both New York State and Massachusetts, and at two localities in Michigan. Noting its close similarity to *Aphis pomi* DeGeer, he tentatively identified it as *Aphis spiraeella* Schoutenden. From material collected at Orono, Maine, Dr. Edith M. Patch described it as *Aphis spiraecola* (Patch 1914).

At that time, and for 10 years more, it attracted little attention, being of very minor importance economically, not noted as attacking any other than species of *Spiraea*. On bridal wreath it rarely occurs on the flowering branches, preferring the adventitious watershoots which project beyond the canopy of flower clusters. In northern New York (region around and to the north of Barneveld, Oneida County), colonies rarely consisting of as many as 100 individuals have been noted from early spring to late September. By the time of the first frosts of October, increasing lignification of the stems has largely dispersed such colonies into a few black, winged adults surrounded by six to nine bright green nymphs on the underside of the leaves. In the next few weeks, the increase in numbers of both adults and nymphs almost covers most of the underside of such leaves as remain on bridal wreath, and leaves which above are turning yellow, orange and purple, from below appear bright green from the aphids resting and feeding on them. By the end of October, many nymphs and adults are moving downward onto the main branches, and shining oval green eggs, subsequently turning black, will be noted crowded into every crevice beneath loose bark or at the axils of twigs. Despite this deflection, the colonies on the leaves appear to be as large as previously, but this is presumably due to an increase in the size of the individual nymphs. Even after killing frosts in early November and continuing throughout the month until all the leaves have turned brown or dropped off, both adults and nymphs persist on the leaves, especially on the more hardy, cultivated species of *Spiraea* of which the leaves are longest green.

Dozens of ornamental species and horticultural varieties of *Spiraea* are grown in the northern United States, besides two wild, endemic species: Meadowsweet or Pride of the Meadow, and Hardhack or Steeplebush, which presumably were the original hosts. These have an extensive distribution in burned-over or deforested areas of minor agricultural value, mingled with poplar, huckleberry and moss, or on stream or lake margins, or along roadsides. On both its wild and cultivated hosts, this aphid—rarely so abundant as to be actually injurious to the host, definitely causing no stunting of watershoots, nor curling of leaves at any time—may be considered as extremely well adjusted to its specific ecological niche, which presumably it had unobtrusively occupied for a long time before being observed by an entomologist.

The change in status from an obscure inhabitant of a wild host to a major insect pest of an economic crop is possibly best authenticated in the case of the Colorado potato beetle as being due to the constantly expanding area over which potatoes are grown. For many other insect pests, the extension of their range and the intensity of their damage is due to accidental introduction by man from areas in which they are but minor pests. But in all these cases, climatic conditions were similar, and the new economic hosts attacked, if not identical, were at least botanically closely related. By contrast, the spirea aphid seems unique for its dispersion to the semi-tropics, and shortly thereafter to the tropics, almost necessarily required a complete change in hosts. To be sure, many of the hosts subsequently reported as infested, possibly only experimentally so far as the aphids were concerned, belong to the Rosaceae, but the most important are widely different botanically. One can but speculate as to what factor caused such a broadening, non-specializing change in its character without loss of

its ability to survive on the comparatively rare spirea plants in the sub-tropical regions to which it had spread. Such a loss in specificity, for which there is no apparent reason, was indeed a necessity if it were to disperse widely and survive outside its limited original environment.

Citrus growers in the southwestern part of the orange belt of Florida in April 1924 noticed a very marked curling and rosetting of the new flushes of growth of their trees, and by June of the same year, this new affliction had assumed the proportions of serious injury all over the State (Watson & Beyer 1925). No other aphid than *Aphis spiraecola* produces such marked and very obvious distortion of citrus leaves, and this in very marked contrast to the absence of such effect on its original host.

Such conspicuous injury could not long escape observation by entomologists wherever it might occur, and specimens were collected by Mr. H. K. Plank on citrus at Central Jaronu, Cuba, June 15, 1926, which were identified by Dr. P. W. Mason as *Aphis spiraecola*. This record was sent to Mr. J. A. Hyslop, at that time in charge of the Insect Pest Survey of the Bureau of Entomology, by Mr. D. L Van Dine, Director of the Cuba Sugar Club. Such a record is by no means surprising, for Cuba is not far from Florida. But in the same year, on October 23, 1926, Mr. S. D. Whitlock "intercepted" this aphid on grapefruit foliage at Mayagüez. Puerto Rico (Wolcott 1948). This is really a noteworthy jump, for Puerto Rico is far from any continental area, and indeed is little closer to Florida than it is to New York.

We do not know how *Aphis spiraecola* reached Cuba and Puerto Rico so soon after it had become wide-spread and well established in Florida, for its importation in nursery stock seems unlikely. Prof. Watson stated emphatically that in Florida it is "spread by flight, not by autos, trains or nursery stock." The historic hurricane of San Ciprián hit Puerto Rico in 1928, or 2 years after the aphid had been observed there. The usual direction of hurricanes approaching and passing Puerto Rico is NNE, NE and ENE, but this does not eliminate the possibility of aphid dispersion by such disturbances, for the back-wash of hurricane winds, traveling in the opposite direction, are almost equally effective in the long-distance transportation of small insects.

Judging by our observations in Puerto Rico, however, *Aphis spiraecola* does not confine its attack to imported nursery stock, if that is thought to be the original source of infestation. Old and well-established commercial grapefuit groves rarely show signs of its presence. The conspicuous rosetted watershoots most often occur on roadside volunteer seedlings of sweet or sour orange. In part, this may be because nobody in Puerto Rico for many years past has been setting out commercial groves, but in the one new experimental orange grove at the Lajas Sub-Station, heavy infestations were noted in January 1952. Indeed, as citrus growing is no longer an important industry in Puerto Rico, the appearance of one more comparatively minor insect pest of citrus in 1926 was a matter of little importance, then or subsequently, if this were the only host attacked in the tropics.

The "bunchy-top" disease of papaya, becoming increasingly abundant and serious in preventing the commercial expansion of papaya growing in Puerto Rico, was of especial interest to Mr. José Adsuar as he was beginning to specialize in virus diseases. After he, with the cooperation of Mr. Francisco Seín in separating out only the males of *Empoasca papayae* Oman (Seín 1947), had proved that these leafhoppers were the only vectors of this disease, his continued studies discovered a new mosaic disease of papaya on the South Coast of Puerto Rico at Ponce and Guánica. It was invariably associated with infestations of the spirea aphid, of which collections identified by Dr. P. W. Mason were made from seven different papaya groves in March 1945, and repeatedly observed in subsequent years. This was not only a new disease, but a new host for *Aphis spiraecola*. Laboratory tests showed the spirea aphid to be the vector (Adsuar 1946), and in the field these aphids were found to be so omnipresent that prevention of infection in new papaya groves nearby proved impossible. Personal inspection (Martorell & Adsuar 1952) found both aphid and disease in similar limited areas in Cuba and Florida; the aphid only in Jamaica and St. Thomas, and neither aphid nor disease on papaya in Hispaniola. Eradication of all mosaic plants would appear to be the only practical method of preventing the further

extension of this serious disease from the limited areas where it is now known to exist. As this is nowhere being done, the future outlook for papaya production is not bright.

The outbreaks in recent years of the green peach aphid, *Myzus persicae* Sulzer, on tobacco in the States and subsequently in Cuba, Santo Domingo (Beinhart 1952) and Puerto Rico (Wolcott 1952), seemed so inexplicable in the tropics as to justify a search for alternate hosts during the summer period when tobacco is not being grown. So far as known, no peach trees still exist in Puerto Rico, but the endemic *Prunus occidentalis* Sw. occurs in the mountainous heights of the western end of the Island. Locally called "almendrón" (not to be confused with "almendro" or tropical almond, *Terminalia catappa* L.), this tree is of more especial value because its wood has proved to be notably resistant to the attack of the West Indian dry-wood termite, *Cryptotermes brevis* Walker (Wolcott 1950), and to a rather limited extent its planting is being pushed by the local Forest Service. If the implication of "green peach aphid" meant anything for this new pest of tobacco, certainly trees of almendrón should be examined for aphid infestation. In an abandoned nursery of these trees in the Doña Juana Forest of the Toro Negro Unit, a few adults and numerous nymphs of *Myzus persicae* were repeatedly collected in the winter and spring of 1953, but Miss Louise M. Russell noted that fully 85 per cent of the specimens were of *Aphis spiraecola*. All the colonies were small, and the crumpling and distortion of the leaves so characteristic of infestations on citrus were barely perceptible on the tender terminal leaves of *Prunus occidentalis*, and had been completely outgrown or had disappeared on the older leaves.

*Aphis spiraecola*, as identified by Miss Russell, was found on the endemic tree locally called "corcho prieto," *Torrubia fragrans* (Dunn-Cours) Standley, of the family Nictiginaceae: heavy infestations on the underside of the leaves of tender watershoots, between Cayey and Aibonito in January 1953. If this was a tentative infestation, one could hardly thus consider an enormous mass infestation on the tender leaves of "jobo" or hog plum, *Spondias mombin* L., of the family Anacardiaceae, brought from Vega Alta by Dr. Frank Ross in March 1953. Even more extensive was that on cultivated coriander, *Coriandrum sativum* L., of the family Amiaceae, brought from the Isabela Seed Farm by Mr. Arturo Riollano. Mr. Julio Bird found heavy infestations on salvia, *Pluchea purpurascens* (Sw.) DC, at Aibonito. In the greenhouse ot Río Piedras, Mr. José Adsuar found the pods, and to a lesser extent the leaves, of an introduced ornamental, *Calliandra inaequilatera*, heavily infested. Possibly these are only tentative and experimental infestations, comparable to the rather extensive list given by Prof. Watson in Florida, and the even longer list compiled by Mr. Kelvin Dorward, in charge of the Economic Insect Detection and Reporting Section of the Bureau of Entomology and Plant Quarantine. But they unquestionably indicate an aphid no longer confined to a single host. The spirea aphid appears ready and able to try almost anything, with ominous possibilities of becoming an even more serious pest of economic plants that happen to meet its increasingly elastic host requirements.

The dispersion of *Aphis spiraecola* to the semi-tropics of Florida, and on to the Greater Antilles, was paralleled at a somewhat later date by occurrence on the Pacific Coast. Dr. E. O. Essig[1] first collected this species on the University of California campus at Berkeley, August 27, 1931, on *Erica*. A few days later, P. S. Bartholemew found it on *Cotoneaster* at Stanford University, and in March of the following spring at the same locality on *Spiraea*. Numerous collections on a variety of hosts have been made subsequently by various collectors in northern California, according to Dr. Essig, but dispersion northward has been slow. The first record for the State of Washington was on August 14, 1949, on *Sorbus* at Seattle, and for Oregon: June 1, 1950 at Medford on *Laurestinus* by L. G. Gentner. *Aphis spiraecola* was found by Dr. E. A. Michelbacher on loquat at Riverside, California on April 8, 1936, and subsequently on orange at the same locality, but its abundance on citrus in California never assumed the epidemic proportions that it had initially shown in Florida.

Dispersion to the continental tropics

[1] Personal communication.

from its original range was much more rapid than to the western United States. Specimens collected in Honduras (Anon. 1928) by R. W. Westmoreland on citrus and sent to M. M. Yothers in Florida, specifically identified in the U. S. National Museum, definitely fix the date for Central America at 1928. An old Florida citrus grower in Honduras claimed that the aphid had been there for at least 10 years previously, but lacking the evidence of actual specimens, one may doubt such early occurrence, for *Toxoptera aurantii* Fonscolombe causes a similar but not such severe curling of the leaves, which in retrospect might be remembered as the tight rosetting resulting from infestation by *Aphis spiraecola*. In March 1933, G. H. Ballou submitted specimens to the U. S. National Museum collected on citrus in Costa Rica, presumably indicating wide dispersion in Central America, but unrecorded elsewhere there and possibly in northern South America because of lack of entomologists to make collections.

To date, *Aphis spiraecola* is not known to occur south of St. Thomas, U. S. Virgin Islands, in the Lesser Antilles. In Barbados, Trinidad and British Guiana, personal inspection by Dr. Luis F. Martorell looking for leafhoppers on papayas in the spring of 1953 failed to indicate the presence of the aphid there on this host. One can but speculate whether the impetus for dispersion has passed, and that the spirea aphid will not invade South America. Possibly all the new records on unanticipated host plants may be merely a temporary interest by plant pathologists and entomologists in Puerto Rico intent on possible vectors of plant diseases. But, considering its past, one may rather expect a continuing extension of dispersion of *Aphis spiraecola* Patch on an ever increasing number of hosts.

## LITERATURE CITED


Adsuar, José. 1946. The Transmission of Papaya Mosaic by the Green Citrus Aphid, *Aphis spiraecola* Patch. P. R. Agr. Expt. Sta. Tech. Paper No. 2.

Anon. (Editorial) 1928. Fla. Ent. 11(4): 53.

Beinhart, E. G. 1952. Green Peach Aphid on Tobacco in the Dominican Republic. Science **116**: 713–14.

Gillette, C. P. 1910. Plant Louse Notes, Family Aphididae. JOUR. ECON. ENT. **3**: 404.

Martorell, L. F., and José Adsuar. 1952. Insects Associated with Papaya Virus Diseases in the Antilles and Florida. JOUR. ECON. ENT. **45**: 861–9.

Patch, Edith M. 1914. Maine Aphids of the Rose Family. Maine Agr. Expt. Sta. Bul. **233**: 270.

Seín, Francisco, and José Adsuar. 1947. Transmission of the Bunchy-Top Disease of Papaya (*Carica papaya* L.) by the Leafhopper, *Empoasca papayae* Oman. Science **106**(2745): 130.

Watson, J. R., and A. H. Beyer. 1925. Controlling the Citrus Aphis. Fla. Agr. Expt. Sta. Bul. **174**.

Wolcott, G. N. 1948. The Insects of Puerto Rico. Jour. Agr. Univ. P. R., **32**: 151.

Wolcott, G. N. 1950. An Index to the Termite Resistance of Woods. Río Piedras Agr. Expt. Sta. Bul. **85**.

Wolcott, G. N. 1952. Migrating Aphids. Science **116**: 43–4.


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The Nation Pest Control Association, Inc. will hold its annual convention, October 18–21, at Miami Beach, Florida.

Convention headquarters will be the Hotel Di Lido, Miami Beach's newest and largest hotel.

# The California County Agricultural Commissioner's Place in the Plant Quarantine Structure[1]

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The Agricultural Commissioner holds a county office originally created the year after passage by the California Legislature in 1880 of the first plant pest law in the United States. California statutes were enacted in 1881 to promote the horticultural interests of the state by giving plant quarantine authority to a state board of three members and by providing for appointment by the governing body of each county of a board of three horticultural commissioners vested with authority similar to that of the state board. Subsequently the state and county authority was vested respectively in the Director of the California Department of Agriculture and in the County Agricultural Commissioner for each county.

A number of duties other than plant pest quarantine are performed by these officers. Some of these are enforcement of standardization laws regulating the packing and labeling of fresh produce, abatement of argicultural pests including field rodents and weeds, and bee disease quarantine and abatement, none of which is within the scope of this discussion.

The Director of the California Department of Agriculture is appointed by the Governor of the State. The other officers and employees of the Department are under Civil Service. County Agricultural Commissioners serve in the 52 agricultural counties of the 58 counties in California. Work needed in the other counties is done by the state. The Agricultural Commissioner is appointed by the governing body of the county, the Board of Supervisors, from a list of eligibles furnished by the State Director who holds periodic examination of applicants for certificates of qualification. County Deputies and Agricultural Inspectors appointed by the Commissioner must be qualified by examinations given by the Director or by the Civil Service Commission of the county.

The duties of the Director of Agriculture and of the County Agricultural Commissioners are fixed by the Agricultural Code of California. The Director of Agriculture is the chief enforcing officer of all plant quarantine activities. He issues exterior and interior quarantines and corollary rules and regulations, maintains inspection stations near state borders or when necessary, at other places within the state. He conducts pest eradication campaigns.

The County Agricultural Commissioner is named an enforcing officer of all laws, rules and regulations relative to the prevention of the introduction into or dissemination within the state of pests and as to such activities is under the supervision of the Director. The Commissioner with his Deputies and Inspectors are further appointed by law as State Plant Quarantine Officers for the purpose of certifying to the pest condition or pest treatment of shipments when certification is officially required and for the purpose of enforcing plant quarantine law. He is therefore and at the same time both a county officer and a state officer enforcing state quarantine law. Actions of a Commissioner may be appealed to the Director for final decision. Refusal of any Commissioner to carry out the Director's orders and directions in such matters is neglect of duty.

The County Agricultural Commissioner operates under a county appropriation. His salary and that of his work force is fixed by the County Board of Supervisors. The State by agreement between Director and the Board of Supervisors may pay the county a portion not to exceed $3,000 of the Commissioner's annual salary. The duty of inspection and enforcement belongs to both the Director and the Commissioner. By established custom, the state maintains inspectors at the highway border stations, at the important maritime ports and at certain airports. State inspectors at maritime ports and airports are Federal Collaborators for enforcement of Federal quarantines. In certain instances, County Agricultural Commissioners who may handle inspections at small maritime ports or perform other

[1] Presented at the annual meeting of the Entomological Society of America held at Los Angeles, California, December 7-10-1953.

Federal duties are also Federal Collaborators.

California is one of the states maintaining destination inspection of shipments of potential pest carriers. Shipments arriving at interior destination points by freight, express and parcel post from out of state, and many motor carrier loads not feasible to inspect at state border stations, are inspected by County Agricultural Commissioners. It is in this field of activity and in the certification of pest condition of outgoing shipments to other states that these county-state officers most frequently come to the notice of entomologists in other states. The several notice forms and certificate forms used in California as tools of plant quarantine use the State Plant Quarantine Officer title but may show also the title of County Agricultural Commissioner. This can be confusing to one who is not informed of the fact that in either capacity the authority exercised is state derived and state controlled. As a county officer the Agricultural Commissioner is empowered by state law to exercise within the county boundary at his own discretion, virtually the same authority as is granted the Director with statewide jurisdiction.

The Commissioner may quarantine, serve and enforce pest abatement notices and conduct pest control and eradication projects. These localized quarantine actions may be unrelated to matters of state interest. Where they are of a purely local nature, the state exercises no control. However, no quarantine may be placed by one county against another except with the approval of the Director, and of course no county may place a quarantine against another state. In matters of statewide concern and therefore also of local concern, the commissioner may and usually does take action under his own authority to assist the state program by such measures as the holding of infested material or the abatement of infestations. In brief, the Commissioner acts under the State Director's control in matters of statewide concern and acts at his own discretion in matters of local concern.

Within California there are many zones of different sizes free or virtually free of certain damaging pests which are of general occurrence in most areas of potential distribution in the state. Mountain ranges and stretches of native brush frequently retard the natural spread of pests from one portion of the state to another and in some instances from one part of a county to another part just as such barriers protect many of the Western States against intrusion of pests except by the hand of man. When it appears feasible to protect an important section of the state from a pest occurring in another section, action is usually taken by the state. Enforcement of such state action is wholly or chiefly done by the counties. In some instances a group of counties may take concerted action, usually with the active advice of the state. The greater the area of general occurrence of the pest in relation to the size of the area to be protected, the more the responsibility for initiation and enforcement of protective measures lies with the county.

The California red scale, *Aonidiella aurantii* (Mask.), has long been the target of county quarantine action and its handling is an excellent example of a situation in which the state is a friendly bystander. The most costly pest of citrus in the state, this scale is firmly established and common in most of the citrus growing areas. From a statewide point of view, it therefore is not a quarantine responsibility of the state. The several important citrus areas relatively free of this scale and susceptible to severe damage by it are in a few valleys and one entire county, each protected by mountain barriers against natural spread of the insect. Action to delay the artificial introduction and the establishment of the pest is taken in each case by the County Agricultural Commissioner at local expense. The pattern of action is that which must be followed in all effective quarantine procedure and necessarily includes inspection of all incoming host material supported by treatment or origin certification when feasible and backed by survey of the protected area and prompt suppression of incipient infestations.

California red scale is scarce in Ventura County, which has more than 40,000 acres of citrus within its borders lying virtually in one great valley protected by mountain barriers. This county has maintained, at county and grower expense for more than 30 years, a vigorous eradication program against any infestation found in its groves. Citrus trees may not be imported from other citrus areas except un-

der exceptional circumstances of pre-inspection and special permit and all citrus trees from any source must be fumigated in county fumigation chambers before planting. This program has been of great profit to the citrus growers of the county but could not have been justified as a state supported project.

Quarantine relationships between the counties and the State of California show many similarities to the quarantine relationships between the states and the Federal Government in their mutual obligations to perform cooperatively and in their responsibility for independent action. The notable differences seem to be that the County Officer must be appointed from a list provided by the state, is a servant of the state in quarantine matters, and his quarantine actions are governed by state law.

SUMMARY.—The County Agricultural Commissioner is a county-state officer appointed by the county governing board from a list qualified by state examination. His salary, except for part paid by the state, and other expenses are paid from county appropriations. He is a State Plant Quarantine Officer enforcing state laws under the control of the State Director of Agriculture. He acts as a county officer on his own initiative in matters of local concern.

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# California's Plant Pest Control and Quarantine Program[1]

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It should be understood that this discussion of "California's Plant Pest Control and Quarantine Program" will be limited to the regulatory and control aspects as administered by the State Department of Agriculture and the County Agricultural Commissioners and will not touch on the research and extension activities carried on by other governmental agencies and by private industry.

Perhaps it might be well to mention first of all that in California we have by mutual agreement and general understanding a well-defined field of responsibility for each of the publicly financed agencies dealing with agriculture. The State Department of Agriculture at the State level, and the County Agricultural Commissioners, County Sealers of Weights and Measures, and County Livestock Inspectors at the County level handle the regulatory, service, and control work. The University of California, through its agricultural experiment stations and agricultural extension service, handles the research, biological control, and extension work.

Because California produces well over 200 different crops and has a wide diversity of climate we are particularly vulnerable to introduced pests. Usually somewhere in the State there can be found the proper host and ecological conditions for establishment of one or another of the insects or plant diseases that are serious problems in other states and foreign countries.

While we have this disadvantage, we have on the other hand a distinct advantage in being so geographically isolated as to preclude the entry of new pests by natural spread. For these reasons it is both important and feasible to maintain a comprehensive plant quarantine and pest control structure.

Our State law defines pest as "any of the following that is or is liable to be dangerous or detrimental to the agricultural industry of the State: (1) any infections, transmissible, or contagious disease of plants, or any disorder of plants which manifests symptoms or behavior which the Director, after investigation and hearing, finds and determines to be characteristic of an infectious, transmissible, or contagious disease. (2) Any form of animal life. (3) Any form of vegetable life." It may be seen that this definition is broad enough to cover any form of animal or plant life or any virus disease that may be dangerous or detrimental to our agricultural industry.

The law also states that the Department shall "prevent the introduction and

[1] Presented at the meeting of the Entomological Society of America held at Los Angeles, California, December 7–10, 1953.

spread of injurious insect or animal pests, plant diseases, and noxious weeds." In an effort to accomplish this objective we have set up a double line of defense. The first is prevention of the introduction of new pests. We attempt to do this through our quarantine structure. Our second line of defense consists of a continuing survey to detect incipient infestations of new pests before they become widely spread, and the eradication of such new infestations whenever feasible and practical.

PLANT QUARANTINE.—In plant quarantine inspection work we have two general types of authority. One is the power to make regulations governing movement of the hosts of specific pests, and the other is the power to take action against shipments based on the presence of pests or the likelihood of their being present. Quarantine regulations are placed in effect only after careful study of the need for such action, and after an evaluation of the proposed restrictions, using as a yardstick the principles of plant quarantine adopted by the National Plant Board. They are also reviewed periodically to determine whether they may be modified or revoked. As a result we believe that our regulations are constantly kept on a sound biological basis.

It is and has been our policy for many years to allow entry under treatment and certification whenever a satisfactory treatment is known, rather than to prohibit such entry. At the present time we have 18 such formal quarantines directed against other states and 13 directed against portions of our own state. Of the 18 exterior quarantines only six have prohibitory features and with one exception all of these are directed against plant diseases. We also enforce seven Federal domestic quarantines which restrict the interstate movement of certain plants and plant products.

All nursery stock and other plant material capable of carrying pests, whether moved by nurseries or private individuals, are required to be held for destination inspection when entering the state or when moving within the state. Inspection is then made to determine compliance with state or federal quarantine regulations and to determine freedom from the pest concerned and from other pests not specifically quarantined against. An exception to the requirement of destination inspection is material moving under the so-called "pinto tag" program by which nurseries meeting certain standards of cleanliness are permitted to ship stock within the state on the basis of certification at origin. This privilege applies only between counties participating in such an agreement and is subject to certain restrictions as to the type of stock and the areas to which it may be so shipped.

Plant quarantine inspection is carried on in three different general areas of the state—at the borders, at the maritime ports, and at interior points. Maritime inspection, which also includes the airplane inspection, is handled by state crews headquartered at San Francisco, San Pedro, and San Diego. At the minor ports, where off-shore ships dock only occasionally, the work is done by the local County Agricultural Commissioners. Maritime work includes foreign quarantine enforcement as well as the handling of material from Hawaiian and other domestic ports. Enforcement of federal foreign quarantines is done under federal supervision with our men acting as collaborators. During 1952, 16,936 shipments arriving by vessel or airplane were rejected because they were infested with pests or did not comply with state or federal regulations.

Border inspection is handled at 16 permanent and one seasonal station on the main highways leading into the state. All of the stations are manned by state personnel. Plant material carried by motorists and bus passengers is inspected. Truckloads are cleared as to compliance with quarantine regulations, but the actual inspection for pests is usually made at ultimate destination by the local Agricultural Commissioner. In 1952 about $3\frac{1}{3}$ million vehicles carrying over 9 million passengers were inspected. A total of 87,592 lots of plant material moving in violation of quarantine regulations or infested with pests were intercepted. Most of this number (76,504 lots) were declared by the passengers after they found out what we were looking for, but 11,088 additional lots were found by actual inspection of the vehicles. We recognize that border inspection is inconvenient to the traveler and is considered by some as an infringement of their constitutional rights. By instituting an on-job training program for our inspectors we have been able

to improve our public relations and reduce the number of complaints.

Rail, express, parcel post, and truck shipments moving interstate or intrastate are inspected at interior points by County Agricultural Commissioners acting under state law. In 1952, 9,651 interstate and 1,886 intrastate shipments were rejected, representing 3.5 per cent and 1.5 per cent respectively of the total number of shipments inspected. The incidence would no doubt be higher if shippers did not know that their material was subject to destination inspection.

People sometimes wonder if we actually prevent any "bugs" from coming in or whether we are just stopping host material that might act as a carrier. The facts are that in 1952 pests were found 18,306 times in material coming through our maritime ports, and 26,322 times at our border stations. All of these were not major pests, but our maritime inspectors did intercept 54 lots of fruit flies and 85 lots of citrus canker, while our border inspectors intercepted 457 lots of apple maggot, 152 of cherry fruit fly, 97 of plum curculio, 58 of European corn borer and 35 of cotton boll weevil. Among the serious pests intercepted a lesser number of times were: citrus white flies, pink bollworm, golden nematode, giant African snail, Japanese beetle, and many others.

DETECTION SURVEYS.—The State Department of Agriculture maintains four survey entomologists and three survey plant pathologists on a continuous full time basis. Each is assigned to a district or area of the state to work with the County Agricultural Commissioners in training their personnel, and in developing and coordinating surveys on a statewide basis to detect incipient infestations of new pests. The manpower for these surveys is furnished by the counties and is augmented in some instances by seasonal personnel employed by the state.

These detection surveys are separate and apart from the survey work necessarily associated with eradication projects and the determination of quarantine lines. They are also separate from the routine nursery inspection work carried on by agricultural commissioners under the guidance of state nursery inspectors.

As previously stated, the objective is to detect incipient infestations of new pests—not to take an insect census or determine population densities. They are generally directed toward a specific pest such as Oriental fruit fly, pink bollworm, golden nematode, Japanese beetle, and the like. When a new pest is found the same force is used initially to delimit the infestation until such time as it is determined whether or not eradication should be undertaken.

ERADICATION.—Insects, plant disease and weed pests toward which eradication effort is directed may fall into one of several categories. If eradication is purely of local rather than statewide concern, probably because the pest already exists elsewhere in the state, the problem is handled by the local Agricultural Commissioner who relies on the state only for technical assistance. If the infestation is rather small and is confined to a nursery or other single piece of property, the Commissioner usually handles the job even though the pest is of statewide concern. He may attain eradication by the expenditure of county funds, by requesting or requiring the owner to take certain action to abate the pest, or by a combination of both. Many incipient infestations of new pests have been eradicated by the Commissioners in this manner without much having been heard about it.

When the pest under consideration for eradication is of statewide importance and the scope of the project is beyond that normally handled by the Commissioner, the state takes on the assignment, usually with the cooperation of the county. The degree of county cooperation varies depending on the importance of the pest to that particular county. Often new pests of prime importance to a large segment of our agricultural industry are found in areas of the state quite remote from the main areas of production of the particular host crop. Examples are cherry fruit fly in Siskiyou County and western grape leaf skeletonizer in San Diego County. On the other hand, when Mexican bean beetle broke out in the heart of a 36,000-acre bean area in Ventura County, local assistance toward its eradication was immediately forthcoming.

Insect eradication projects currently receiving attention of the Department concern cherry fruit fly in Siskiyou County, Hall scale in Butte and Yolo Counties, citrus white fly in San Benito, Fresno and Madera Counties, and Mexi-

can bean beetle in Ventura County. The western grape leaf skeletonizer project in San Diego and Riverside Counties started out as an eradication attempt but has necessarily reverted to a holding program designed to retard spread to the major grape producing areas of the state.

The Hall scale project is being carried out jointly with the U. S. Department of Agriculture which up to now has provided the major part of the funds expended. Since the infestation originated on the U. S. Plant Introduction Gardens at Chico and is known nowhere else in the western hemisphere, it was felt that they had greater than normal responsibility for its eradication.

The separate eradication programs are as varied as the species with which they are concerned and are planned with due regard for the specific biological characteristics of the pest. They do, however, have two major factors in common. Six years has been arbitrarily established as the minimum period of operations. During the first 3 years the treatment measures are applied to all hosts within a predetermined radius of a known infestation. The second 3 years are given over to intensive survey of the treatment area and its extended periphery to assure that there has been no survival or escapes. If at any time during this 6-year period a live specimen of the species under eradication is found, in any stage, the entire 6-year program is reinitiated. Experience has shown that complete confidence cannot be placed in visual inspection or even in trapping, in determining all existing infestation. For that reason the treatment measures are extended to all hosts occurring within twice the radius of the anticipated seasonal spread of the species.

In the field of plant disease we are currently attempting, with the cooperation of the Agricultural Commissioners concerned, to eradicate a virus disease of peach known as yellow leaf roll, which occurs in four counties in the peach bowl area of the Sacramento Valley. We hope that this effort will be more successful than the joint federal-state-county effort to eradicate peach mosaic in southern California. In this latter case we were able to reduce the incidence in commercial orchards to less than one-half of one per cent, but it is apparent that we cannot completely eliminate the disease with presently known techniques.

In addition to our insect and plant disease projects we are attempting the eradication of several noxious weeds on a state-wide basis. In this work the state, county, and landowner each bear one-third of the cost.

When a pest becomes so widely distributed that we are no longer justified in applying eradication or intensive control measures at state or county expense, it then becomes the grower's responsibility to control it on his own property. As a means of protecting the growers our laws permit the County Agricultural Commissioners to serve notices and cause the abatement of such pests when they are allowed to build up so as to constitute a nuisance to adjacent properties.

We do, however, spend state funds in the control of certain species of migratory insects, such as grasshoppers and the beet leafhopper, even though these pests may be of general distribution in the state. This is a policy that has developed over a period of years as it became obvious there were certain types of situations under which producers of important crops could not effectively protect themselves. Both of these pests build up on range lands or waste lands that are often great distances from the crops that they ultimately attack, and the properties on which they build up are owned or controlled by persons having no financial or economic interest in the pest problem that they present.

# Insect Lipids and Insecticidal Action

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The degree of saturation of the lipids of the American cockroach, *Periplaneta americana* (L.), is influenced by the temperature at which the insects are kept. When the insects are held for two or more weeks at a temperature between 17 and 27° C. the iodine numbers for their total lipids range around 72; between 27 and 32° C. the iodine numbers fall to about 60 and thereafter show little furthur decrease with increase in temperature. Also, cockroaches preconditioned for two or more weeks at 23° C. in comparison with roaches preconditioned at 34° C. are more resistant to the toxic action of injected or topically applied DDT when the insects of both groups are held at 23° C. after application of the insecticide (Munson 1953a, 1953b).

Moreover, adult female cockroaches, slightly exceeding males in total lipid content, are more resistant than males to DDT; also in both sexes the total quantity of lipids declines in the last nymphal instar and in adults and resistance declines concurrently. If survival times are plotted versus total lipid content a fairly smooth curve is delineated; but all the survival times (means) for males lie on one side of the curve and for females on the other. The coefficient of correlation (r) for lipid quantity-survival time is +0.81. Thus if a relationship between these two exists it is significant but such a relationship still does not account for all the differences in resistance between the sexes (Munson & Gottlieb 1953).

It has been hypothesized (Munson 1953b) that cockroaches preconditioned at the cooler temperature are more resistant than those preconditioned at the warmer because the less saturated lipids of the former more readily take up DDT in solution thereby decreasing its concentration at a site of lethal action. In line with this hypothesis the larger quantity of lipids in female and in young adults of either sex may be a partial explanation of differences in the resistance of insects of different sexes and ages.

Shortly after the insecticidal properties of DDT were discovered, the compound was reported to be more effective against house flies at lower temperatures than at higher (Lindquist *et al.* 1945) and this observation was soon extended to other insects by Richards & Cutkomp. This negative coefficient of action with temperature has never been satisfactorily explained (Richards 1951). In the work referred to above as the cockroaches preconditioned at 34° C. were kept after application of the DDT at a temperature (23° C.) which was lower than that to which their fats were physiologically adjusted they may be considered to have shown a "negative coefficient of action with temperature" while the cockroaches preconditioned at 23° C. did not.

The present paper has a threefold purpose: (1) to elucidate the above hypothesis regarding liposolubility and insecticidal action, (2) to examine this hypothesis in the light of pertinent literature, and (3) to report additional experimental results bearing upon this hypothesis.

In this hypothesis it is not necessary to postulate that the lipids of the insect as a whole are more affected by temperature than are the particular lipids which are present at the site of toxic action, although such may be, indeed, the case. Presumably lipids at the site of lethal action would fall into the "element constant" category and such lipids are in large part unsaturated; thus one might expect to find the greatest shift in saturation to occur in the neutral fats and free fatty acids. All that is necessary for the hypothesis to be feasible is that the solubility of DDT in fats not at the lethal site increase relatively in comparison with its solubility at the site of lethal action. An example of such a selective change is indicated by the unpublished work of Mr. Thomas Wilson who has demonstrated histochemically that larvae of the yellow mealworm, *Tenebrio molitor*, at cooler temperatures show an increase in phospholipids as well as in oleic acid and triolein but no increase in cholesterol while worms at warmer temperatures have an increase in fatty aldehydes.

If the site of toxic action of DDT were known it would be easier to postulate which lipids are competitive. Present

evidence indicates that DDT has a physiological action on nerve membranes which are lipoidal in nature. Also there is evidence that DDT may inhibit cytochrome oxidase (Review by Chadwick, 1952). Cytochrome oxidase is found largely in mitochondria and to some extent in the plasma membrane (Barron 1952). It is thus possible that the reversible effects may occur at any level from the cuticular lipids to the level of the cellular organelles. At this level information might be secured by the hydrogen centrifuge and a radioactive insecticide.

For the present time both external lipids (cuticular) and internal lipids (lipomicrons of the hemolymph, "reserve lipids," and other lipids not at the site of lethal action) must be considered in the elucidation of this hypothesis. While the internal lipids could exert, probably, a competetive storage influence only, the cuticular lipids could affect the action of the insecticide in three ways: (1) solubilization and facilitation of penetration through the cuticle, (2) solubilization and facilitation of penetration but with some of the insecticide being retained thereby decreasing its internal concentration, and (3) nonsolubilization and prevention of the entry of the insecticide. It is needless here to repeat the evidence that the penetration and effectiveness of several insecticides including DDT is dependent on liposolubility; the papers of Bohm (1951), Dresden & Krijgsman (1948) and others and the book by Richards (1951) review the general aspects of this literature; rather, it will be sufficient to substantiate the three cases above.

Hurst (1949) found mature blowfly larvae, *Calliphora erythrocephala*, extremely resistant when in contact with crystalline DDT at 20° C. but if in contact with it for 2 hours at 36° C., a temperature which presumably liquefied their cuticular lipids, sufficient DDT was absorbed to cause paralysis when the temperature was lowered. If the temperature again was raised the larvae recovered and this effect was reversible many times. On this and other evidence Hurst suggested that the phenomena represented an equilibrium condition in which DDT present in the cuticular lipids could act, when thrown out by chilling, on the peripheral nervous system. Here the lipids seem to bar passage of the poison at one temperature, facilitate its passage at another, and act more effectively as a competitive site at a higher than at a lower temperature. It seems to the present writers that, while Hurst has effectively pointed out an equilibrium between DDT in lipids and at a site of toxic action which may be the literal condition in this particular case, the concept must be extended to cover fats within the insect in order to include all cases of reversible effects especially those obtained when the cuticle is bypassed by injection (Munson 1953b, Vinson & Kearns 1952, Woodruff 1950).

Unfortunately very little data on the solubility of DDT in lipids at different temperatures are available. The data of Gunther (1945) provide temperature-solubility curves of DDT in various organic solvents; and some of these curves show sufficient change in slope to permit the above hypothesis if similar curves occur with lipids. Pradhan *et al.* (1952) extracted the lipids of the exuviae of *Euproctes lunanta* and *Trogoderma granaria*. Those from *Euproctes* melted between 47 to 54° C. and when spread as a thin film on a coverglass rapidly solubilized DDT at 32° C. but not at 10 to 15° C.; while the waxes from *Trogoderma* with a melting range of 77 to 83° C. were an exceedingly poor solubilizer. *Euproctes* larvae were more susceptible to DDT than *Trogoderma* larvae.

By bioassay Bohm has demonstrated the accumulation of DDT in various tissues of the yellow mealworm larvae and Colorado potato beetle larvae, *Leptinotarsa decemlineata* (Say). There seems to be a considerable amount accumulated in the fat bodies of these insects. Lindquist *et al.* (1951) in a study of the penetration of radioactive DDT into house flies report that 26 to 34 per cent is in the internal organs the remainder being held back by the cuticle. Thirteen per cent was reported as present in the body fluids but as these fluids were rinsed from the animals with distilled water it would seem to the present authors that a part of this might be from the fat body as this breaks down rapidly after death and is also very sensitive to hypotonic solutions. A study of the penetration of DDT into the cockroach at different temperatures by Vinson & Kearns (1952) shows greater penetration at higher temperatures and is in line with the hypothesis given in this paper.

The solution of DDT in mammalian fats when small chronic doses are administered and the later appearance of symptoms of DDT intoxication in these animals or of the DDT in their milk is well known (see Brown 1951). The extraction of DDT from human fat has also been reported (Pearce *et al.* 1952). It is therefore somewhat astounding that the storage of DDT in the lipids of insects and the influence of such on the lethal process has received so little attention. In the experimental portion of this paper will be reported the "holding capacity" for DDT of the total lipids of the American cockroach at different temperatures.

If the present theory is valid it would seem that starvation by lowering the quantity of fats would decrease the resistance of insects to DDT. Starved fourth instar larvae of *Anopheles quadrimaculatus* develop DDT symptoms significantly more rapidly and are "knocked down" more rapidly than fed controls (Dr. Jack C. Jones, personal communication). If cockroaches are kept at 17° C. for 2 weeks they are more resistant to DDT than cockroaches kept at 34° C. when both are treated with DDT and kept at 23° C.; but cockroaches kept longer than 2 weeks at 17° C. are no longer more resistant but tend to be less so. These cockroaches feed very little and their loss in resistance may be due to loss in lipids through starvation; on the other hand, starvation may alter some other factor concerned in the toxic action of DDT. It has been observed many times by the senior author that cockroaches treated with DDT and dying long after such treatment under conditions of prolonged starvation will suddenly exhibit typical DDT symptoms. These symptoms may be due to DDT being released from mobilized fats in a manner similar to the accumulation of DDT with long delayed production of its toxic symptoms in the mammal.

In a study with the boll weevil, *Anthonomous grandis* Boh., and other insect pests of cotton Reiser *et al.* (1953) have undertaken to test the very same hypothesis under discussion here. Their data present a strong correlation between the lipid content of weevils as varying with the time of the year and the variations in resistance of the insects to toxaphene; also these authors found that weevils resistant to toxaphene, dieldrin, EPN, and methyl parathion had a higher lipid content than weevils which were susceptible. However the authors noted that in the untreated controls the more hardy also had a higher lipid content. Seven species of insects collected from cotton plants were analyzed for fat content and treated with toxaphene. The authors did not find a relationship between total lipid content and resistance to toxaphene by comparing the species. Also the authors note that boll weevils poisoned with calcium arsenate are more resistant to this poison when their fat content is highest toward the end of the summer; and when mortality from arsenate is plotted against fat content a curve very similar to their lipid content-toxaphene mortality curve is obtained. The authors thereby conclude "The fat content of the boll weevil is not directly related to its resistance to chlorinated hydrocarbon insecticides . . . ." It seems to us that the data of Reiser *et al.* are compatible with an entirely different interpretation which leads to the conclusion that the resistance of the boll weevil to chlorinated hydrocarbon insecticides is directly related to its total lipid content. Reiser and his coworkers state, "The figures show conclusively that surviving weevils (toxaphene-treated) are pronouncedly fatter than susceptible ones. However, this is also true of untreated controls." Since apparently weevils of different ages were used, the control weevils which died were likely older weevils and, as is generally the case with older insects, had less fat.

If the toxaphene ratings of the seven species of insects studied by Reiser *et al.* are plotted against their percentages of unsaturated fatty acids (not against total fat) it is readily seen that five of these ratings fall on a straight line (boll weevil, bollworm, fall armyworm, garden webworm, and cotton leafworm) while two (salt marsh caterpillar and cotton leafworm) are so far off the line as to indicate that any possible influence of the fats is inoperative because of some other factor. Actually this is a good correlation between unsaturated fats and resistance to toxaphene.

The similarity of the lipid content-toxaphene susceptibility curves of Reiser

*et al.* and the lipid content-calcium arsenate curve is likely coincidental. The slight solubility, if any, of the arsenates in fats would indicate no great relationship between the two; but the solubility of the chlorinated insecticide, toxaphene, in fats does indicate a possible relationship. Various arsenates possess a low water solubility which is augmented by higher temperatures. Moreover, they seem to have a somewhat greater solubility in the body fluids of an animal. Although data is not given Reiser *et al.* find an increase in "moisture" corresponding to the increase in fats in boll weevils. It is likely increased water which decreases the toxic effect of arsenate; and this decrease in arsenic toxicity possibly is brought about by the same type mechanism as is here postulated for the lipid soluble insecticides; although of course other unknown factors may be postulated and other mechanisms are conceivable.

Doubtlessly, all insects possess lipids subject to temperature influences and since many of the more effective insecticides have good lipoid and poor water solubility, negative coefficients of action with temperature and preconditioning effects should occur with many compounds and insecticides provided the particular conditions for a given insecticide against a given species and stage of insect are met. An investigation of the literature shows that at least 21 well-known insecticides have been reported to show negative coefficients of action with temperature (Craufurd-Benson 1938, Hoffman & Lindquist 1949, Potter & Gilham 1946, Guthrie 1950, and Woodruff 1950). Among these are such common insecticides as pyrethrum, rotenone, derris, lethane, lindane, nicotine, methoxychlor, terpenol, laurylthiocyanate, and the fumigants, chloropicrin, ethylene dichloride, and dinitrophenol. Curiously enough, to this list of organic insecticides may be added calcium arsenate, basic copper arsenate, acid lead arsenate, and synthetic cryolite (Ellisor & Blair 1940); but the addition of these inorganic poisons is in line with the suggestion above with regard to calcium arsenate and the water content of the boll weevil; that is, it is again the same physical principle but involving water rather than fat solubility. While in the case of some of the fumigants the negative coefficients may be due to adsorption, as has been suggested, in most cases adsorption seems to be ruled out by the method of application.

When tested against the German cockroach, *Blattella germanica* (L.), by topical application the negative temperature coefficient for DDT was much greater than the negative coefficients for pyrethrum and lindane while dieldrin and aldrin gave positive coefficients (Guthrie 1950). With house flies exposed to poisoned surfaces methoxychlor gave as large a negative coefficient as DDT (Hoffman & Lindquist 1949).

Most preconditioning periods reported in the literature have been of such short duration that any changes produced by them in the degree of saturation of the lipids of the "preconditioned" insects would have been trivial. Other than the work of the present authors referred to above two clear cut cases of preconditioning are available. Craufurd-Benson (1938) reared *Ahaserus advena* at 20° and 25° C.; and found the 20° C. beetles definitely more resistant to derris than the 25° C. beetles. Sun (1947) reared the confused flour beetle, *Tribolium confusum* Duv. and the granary weevil, *Sitophilus granarius* (L.), at 25°, 30° and 35° C. and found corresponding M.L.Cs. for carbon disulfide to be 81.5, 73.7, and 48.8 mg/l when the beetles were fumigated at 25° C. Young adults from 30° and 35° C. cultures kept at 25° C. for 4 weeks gave about the same mortality when fumigated as insects reared at 25° C. Thus Sun's results with this well known fat solvent and these beetles closely parallel previous results with cockroaches and DDT (Munson 1953b).

RESULTS OF EXPERIMENTS.—The experimental contributions of this paper were planned to throw light on the hypothesis under consideration in four ways: (1) by determining whether or not the holding capacities of the lipids of an insect for an insecticide at different temperatures are such as to permit the hypothesis; (2) by using insecticides other than DDT on cockroaches preconditioned at different temperatures to extend this aspect of the experimental basis; (3) by conditioning insects other than cockroaches at different temperatures and then treating them with

DDT to broaden this aspect; and (4) by using other compounds to extend the number of them known to show negative coefficients of toxic action with temperature, if such generally occur.

To obtain lipids for the experiments determining the holding capacity the pooled total lipids of 11 male and 10 female nymphal and 4 male and 5 female adult American cockroaches were extracted by methods previously given (Munson 1953a). Recrystallized DDT and methoxychlor[1] were used in these experiments. The insecticides were dissolved in the lipids by warming thus producing supersaturated solutions. The temperature of the lipids was then lowered to a point at which a given quantity of insecticide would remain in solution for about an hour without any visible precipitation. This we shall call "holding capacity." The results of these experiments are shown in figure 1. It must be emphasized that the curves in figure 1 are not solubility curves. Tests with DDT indicate that if the DDT holding capacity curve were shifted to the right 10° to 15° C. it would approximate a solubility curve. For example 27 per cent DDT remains in solution indefinitely at 52 to 55° C. and 20 per cent remains soluble indefinitely at 43° C. Furthermore, if, for example, the 27 per cent solution which is held for an hour at 34° C. with no visible precipitation is kept at the same

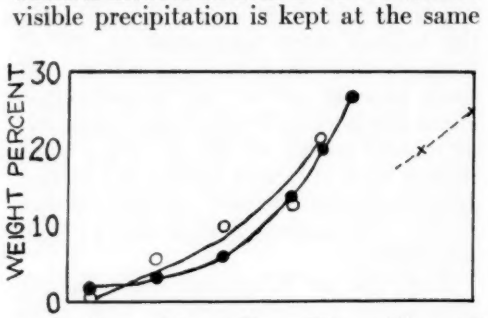


FIG. 1.—Holding capacities for DDT (solid circles) and methoxychlor (open circles) of the total lipids of the American cockroach at different temperatures. Broken line with X symbol represents two determinations of the solubility of DDT in the total lipids.

temperature for 24 hours the DDT will crystallize and the fats will set even though the fats without the DDT normally set fast at around 8° C. Thus the setting point of the lipids increases with increase in the quantity of DDT in the supersaturated solutions. Methoxychlor seems to give a similar picture.

The steep rise of the holding capacity curves between 20 and 30 degrees meets exactly the requirements of the hypothesis for it is generally in this critical range that negative temperature coefficients occur. These curves are somewhat similar to the curves for the solubility of DDT in carbon tetrachloride and chloroform (Gunther 1945).

The data of Busvine (see Brown 1951) indicate that in general compounds chemically allied to DDT are less toxic to *Pediculus* and *Cimex* the greater their liposolubility. From the present hypothesis it is obvious that a slow acting compound which is freely liposoluble might be stored in lipids rather than be available to exert its lethal action. Thus there would seem to be an optimum of liposolubility consistent with strong toxic action.

In the second phase of these investigations nymphs of the American cockroach by the method previously reported (Munson 1953b) were treated externally with chlordane, DDT, fluorine DDT,[2] and bromine DDT.[2] The results of these experiments (1 through 7) are given in table 1. In experiment 1 the cockroaches preconditioned at 34° C. seem to be slightly more resistant to chlordane than those preconditioned at 23° C. when both groups after treatment were kept at 23° C. This is in contrast to experiments 2, 3, and 4 in which the results are highly significant in the reverse direction. The animals in experiment 1 were preconditioned immediately after a hot summer and it was observed that those in the cooler temperature did not feed well. This semi-starvation effect has been noted previously in the results with DDT (Munson 1953b). In the other experiment the animals preconditioned at the cooler temperature did feed more or less normally as they had already become acclimated to cooler temperatures. Thus from the results of the experiments it may be safely concluded that cockroaches preconditioned at cooler temperatures may be more resistant to chlordane, and to DDT, than

[1] The authors wish to thank the Agricultural Chemicals Section of the E. I. duPont de Nemours & Co. for supplying the methoxychlor.

[2] The authors are indebted to the Insecticide Division of the Bureau of Entomology and Plant Quarantine for the bromine and fluorine DDT.

**Table 1.—Survival times of American cockroach nymphs preconditioned at 34° C. and 23° C, and then kept at 23° C. after treatment with the indicated insecticides.**

| Exper. No. | Poison, μg/g | Survival Times of Males | | | | Survival Times of Females | | | | Standard Errors of the Differences Between Means | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 34° C. | | 23° C. | | 34° C. | | 23° C. | | | | | |
| | | No. Insects | Mean Hrs. | No. Insects | Mean Hrs. | No. Insects | Mean Hrs. | No. Insects | Mean Hrs. | 34°–23° C. Males | 34°–23° C. Females | 34° C. Males–Females | 23° C. Males–Females |
| 1 | Chlordane 16 | 19 | 443 | 18 | 343 | 12 | 608 | 13 | 381 | 1.2 | 1.8 | 1.4 | 0.5 |
| 2 | Chlordane 8 | 16 | 627 | 16 | 826 | 9 | 746 | 14 | 917 | 5.4 | 2.2 | 0.8 | 0.3 |
| 3 | Chlordane 16 | 12 | 353 | 13 | 557 | 13 | 461 | 12 | 770 | 2.3 | 3.2 | 1.2 | 1.7 |
| 4 | Chlordane 16 | 13 | 361 | 13 | 745 | 11 | 345 | 11 | 971 | 9.3 | 6.3 | 0.2 | 2.0 |
| 5 | Cl DDT 50 | 15 | 275 | 13 | 468 | 10 | 659 | 12 | 657 | 2.4 | 0.0 | 4.2 | 1.2 |
| 6 | Br DDT 80 | 13 | 423 | 13 | 425 | 12 | 353 | 12 | 733 | 0.0 | 1.7 | 1.1 | 3.0 |
| 7 | Fl DDT 112 | 14 | 372 | 13 | 401 | 11 | 406 | 12 | 634 | 0.3 | 1.5 | 0.3 | 2.0 |

cockroaches preconditioned at a higher temperature when both groups are held after treatment at the cooler temperature. A comparison of cool temperature males with cool temperature females and hot temperature males with hot temperature females indicates no differences between the sexes in resistance to chlordane. Such differences were observed with DDT (Munson 1953b, Munson & Gottlieb 1953). Although there is no valid reason to think that DDT and chlordane have the same fundamental mode of toxic action, the above indicates that the modes of action are indeed different in the two insecticides.

Experiment 5 with DDT is merely a confirmation of former results and was conducted for comparison. It follows the general pattern of previous tests although the differences are less striking than in many of them, in which cockroach nymphs preconditioned at 23° C. were decidedly more resistant than those preconditioned at 34° C. and females were more resistant than the males for a corresponding temperature. The bromine DDT (experiment 6) and the fluorine DDT (experiment 7) follow the trend of DDT; however, more data would be desirable before a definite conclusion on this point is established. The order of toxicity of these insecticides from greatest to least is: chlordane, DDT, bromine DDT, and fluorine DDT.

In the third part of these investigations, pomace flies, *Drosophila melanogaster*, and saw-toothed grain beetles, *Oryzaephilus surinamensis* (L.) were preconditioned at different temperatures and subsequently treated with DDT.

The flies were reared in $\frac{1}{2}$-pint bottles on a cooked medium of corn meal, molasses, agar and water. To this yeast was added after setting. A stock colony of flies was maintained at room temperature (ca. 23° C. thermostatically regulated) and these provided the eggs which gave the experimental flies of which one group was reared at 30° C. and one at 18° C. Adults were removed from the cultures daily so that the adults used in the experiments were the same age.

The beetles were reared on raisins and white flour. The colonies were kept at the preconditioning temperatures (30° C. and 23° C.) for 6 weeks before they were used in the experiments.

Adult flies or beetles were immobilized by chilling and the DDT in 95 per cent alcohol was applied by the wire loop method of Yeager and Munson; the loop was calibrated by the method of Wilson (1949). The loop used delivered a volume of 2.62 microliters and a dosage of 0.026 microgram of DDT was applied to each insect except in experiment 8 in which a double volume was applied. After treatment the insects were kept under starvation conditions in bottles, and kept at 23° C. with frequent observations. Control groups to show the effects of chilling and of the alcohol application produced negligible mortality. The results of these experiments (8 through 15) are given in table 2.

In experiments 8 through 11 the flies obtained from larvae reared at 18° C. are clearly more resistant to DDT than flies from larvae reared at 30° C. when both groups after treatment were kept at 23° C. Likewise in experiments 12 through 15 the beetles from larvae preconditioned at 23° C. are definitely more resistant to DDT than adults from larvae preconditioned at 30° C. The large number of insects involved in each of these tests gives to the large standard errors of the differences between the means (Table 2) high significance.

**Table 2.—Survival times of adult *Drosophila*[1] and adult *Oryzaephilus*[2] treated with DDT[3] and held at 23° C. after preconditioning at indicated temperatures.**

| Exper. No. | Preconditioning Temperatures: 30°C. (Expts. 8–15) No. of Insects | 30°C. (Expts. 8–15) Mean in Hrs. | 18°C. (Expts. 8–11) 23°C. (Expts. 12–15) No. of Insects | 18°C. (Expts. 8–11) 23°C. (Expts. 12–15) Mean in Hrs. | Standard Error of Diff. Between Means |
|---|---|---|---|---|---|
| 8 | 30 | 13 | 57 | 16 | 2.72 |
| 9 | 159 | 13 | 94 | 15 | 2.43 |
| 10 | 60 | 12 | 35 | 17 | 4.43 |
| 11 | 20 | 11 | 25 | 15 | 2.25 |
| 12 | 32 | 79 | 20 | 103 | 1.45 |
| 13 | 40 | 61 | 40 | 88 | 2.43 |
| 14 | 53 | 58 | 49 | 98 | 3.44 |
| 15 | 51 | 46 | 50 | 77 | 2.98 |

[1] Experiments 8 to 11, inclusive.
[2] Experiments 12 to 15, inclusive.
[3] Dose of 0.026 μg/insect except Expt. 8 with dose of 0.052.

The last group of experiments consisted of tests of the toxicities of chlordane, methoxychlor, fluorine DDT, and bromine DDT to adult *Oryzaephilus* reared at 30° C. when these after treatment were separated into groups kept at 8°, 18°, and 34° C. after treatment. However, before these groups were placed at their respective temperatures they were held for varying periods of time at 34° C. (see Table 3) to permit penetration of the insecticides. The method of rearing the beetles and the technique of application of the insecticide was the same as in the preceding experiments except that the insecticides were dissolved in pyridine rather than in alcohol. The pyridine showed little or no toxic effect on control beetles. After treatment the insects were observed and recorded in three symptomatic stages: (1) Alive and apparently unaffected, (2) knocked down and able to move one or more appendages, and (3) dead as indicated by complete lack of movement.

The results of these experiments at sample times after treatment are recorded (experiments 16 through 37) in table 3. In each of the three groups in experiment 18 there were 40 beetles; in experiments 23, 24, 34, and 35 there were 15 beetles in each group; in experiments 25 and 36 there were 60 beetles per group; in all the remaining experiments there were 30 beetles per group. In columns 5 and 6 of table 3 the differences in the percentages alive at the indicated temperatures are recorded along with a minus sign indicating that the number alive was smallest at the lower temperature (indicating a negative coefficient of action) or a plus sign indicating that the percentage alive at the lower was the greater (indicating a

**Table 3.—Differences in resistance of *Oryzaephilus* at different temperatures to chlordane, methoxychlor, fluorine DDT and bromine DDT.**

| Exper. No. | Insecticide Used | Dosage in μg/Beetle | Penetration Time at 34° in Hrs. | Time After Treatment in Hrs. | Per Cent Active at Lower Temp. Less Per Cent Active at Higher: 8° C.–18° C. | 18° C.–34° C. |
|---|---|---|---|---|---|---|
| 16 | Chlordane | 0.026 | 0 | 10 | −77 | +27 |
| 17 | | 0.026 | 2 | 30 | −66 | +36 |
| 18 | | 0.026 | 6 | 34 | −16 | − 8 |
| 19 | | 0.013 | 10 | 100 | −10 | +17 |
| 20 | | 0.003 | 24 | 200 | −17 | +50 |
| 21 | Methoxychlor | 0.052 | 0 | 10 | − 7 | −17 |
| 22 | | 0.052 | 2 | 30 | 0[1] | − 3 |
| 23 | | 0.052 | 6 | 12 | 0[1] | −13 |
| 24 | | 0.026 | 6 | 12 | −13 | +13 |
| 25 | | 0.013 | 10 | 30 | − 7 | −40 |
| 26 | | 0.006 | 10 | 24 | −27 | −33 |
| 27 | Fluorine-DDT | 0.091 | 0 | 10 | −20 | −27 |
| 28 | | 0.091 | 2 | 7 | −24 | −10 |
| 29 | | 0.022 | 6 | 24 | 0[1] | −37 |
| 30 | | 0.022 | 10 | 24 | −14 | −16 |
| 31 | | 0.011 | 24 | 30 | −20 | +10 |
| 32 | Bromine-DDT | 0.052 | 0 | 10 | −10 | −17 |
| 33 | | 0.052 | 2 | 6 | −33 | 0 |
| 34 | | 0.052 | 6 | 22 | 0[1] | − 3 |
| 35 | | 0.026 | 6 | 22 | − 7 | + 7 |
| 36 | | 0.013 | 10 | 24 | −22 | −23 |
| 37 | | 0.006 | 24 | 48 | − 7 | −30 |

[1] All knocked down or dead at both temperatures.

positive coefficient of toxic action). The coefficient of action for 8° as compared with 34° may thus be simply obtained by the algebraic combination of the two columns. The results show beyond doubt that all the compounds have a negative coefficient of action. With chlordane the coefficient is negative between 8° and 18° C. but it is positive between 18° and 34° C. For methoxychlor, bromine DDT and fluorine DDT the coefficient is negative throughout the range.

Fan *et al.* in 1948 (Richards 1951), found that DDT did not produce negative temperature effects if high dosages were employed *Aedes* and *Chaoborus* larvae. Hoffman & Lindquist (1949) obtained the same result with BHC and house flies. Actually all the dosages in the present experiments may be considered moderately low dosages but the lower of these (i.e. below 0.026 mg./beetle) for the three DDT analogs in table 3 seem to indicate a somewhat greater degree of action at lower temperatures but it is difficult to assess this as the penetration time if these low-dosage experiments was also increased and the trend, if real, cannot be ascribed to either cause. That negative coefficients should become obscured if not completely obliterated with higher dosages is in line with the present hypothesis for it is not difficult to imagine that the competitive site (lipids) could be so overwhelmed by high doses as to exert little influence on the effective dosage. Additionally the mortality "curves" at high dosages would be approaching an asymptotic minimal survival time.

While all the animals knocked down in experiments 16 through 37 may be considered doomed the fact remains that all are not dead at a given time. If only the animals "completely dead" are considered the picture with regard to the "coefficients of action" becomes somewhat different. In table 4 somewhat more detailed data are given for experiments 16, 28, and 33. In experiment 16 the coefficient of toxic action as measured by the number of dead beetles is negative in the early course of the test but a reversal occurs by 100 hours. In experiment 28 (fluorine DDT) the results are clearly negative by comparing the number alive but comparing the number dead at 7 hours the coefficient is slightly positive between 18° and 34°; by 24 hours the coefficient for death is clearly positive throughout the range. Similar results are indicated by experiment 33 and, indeed, 16 of the 22 experiments indicate the same results to a greater or less degree.

The question naturally arises: Why should the coefficients be negative from one criterion and positive from another at the same time? The answer possibly lies in a complexity of equilibria and reactions occurring simultaneously. While one may not weigh or even surely list these factors at the present time some are subject to surmise. Firstly, there would be the fundamental lethal reaction, or reactions, which produces knockdown or death. This conceivably could be chemical with its velocity accelerated by increase in

**Table 4.—Distribution of *Oryzaephilus* into three symptomatic stages[1] at three different temperatures after treatment with insecticides.**

| Exper. No. Insecticide μg/Insect | Hours After Treatment | Temperature and Symptomatic Stages | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 8° C. | | | 18° C. | | | 348° C. | | |
| | | A | M | D | A | M | D | A | M | D |
| 16 | 5 | 3 | 11 | 16 | 18 | 7 | 5 | 16 | 12 | 2 |
| Chlordane | 30 | 1 | 12 | 17 | 14 | 7 | 9 | 16 | 3 | 11 |
| 0.026 | 100 | 0 | 11 | 19 | 3 | 4 | 23 | 0 | 0 | 30 |
| | 300 | 0 | 2 | 28 | 0 | 0 | 30 | | | |
| 28 | 7 | 1 | 23 | 6 | 8 | 18 | 4 | 11 | 8 | 11 |
| Fl. DDT | 24 | 0 | 17 | 13 | 0 | 5 | 25 | 1 | 2 | 27 |
| 0.091 | 72 | 0 | 5 | 25 | 0 | 0 | 30 | 0 | 0 | 30 |
| 33 | 7 | 0 | 30 | 0 | 10 | 18 | 2 | 10 | 8 | 12 |
| Br. DDT | 24 | 0 | 27 | 3 | 0 | 11 | 19 | 3 | 4 | 23 |
| 0.052 | 120 | 0 | 7 | 23 | 0 | 0 | 30 | 0 | 0 | 30 |

[1] A. alive; M moribund; D, dea[d]

temperature. Then if the hypothesis in this paper represents reality, removal of the poison from the site of lethal action would be increased by increase in temperature. If the poisoning process continues for a sufficient period of time during which the insects either artificially, as in these tests, or by knockdown are deprived of food, the depletion of their reserve fats would return some of the insecticide to the site of lethal action. This fat depletion should be more rapid at higher than at lower temperatures. Then to be considered are rates of absorption, rates of detoxification and/or excretion along with other general physiological rates such as circulation of the hemolymph and metabolic rates and rates of specific physiological processes such as the repair or replacement of tissue components destroyed or inactivated by the insecticide. All of the above and other unknown factors, every one of which is likely responsive to temperature, may exert some influence on the fundamental killing process. The difficulty lies in determining and evaluating these factors. For example, one might say that in experiment 33 at 34° C. at 7 hours more animals are both alive and dead (fewer of course, near death) than at 8° C. because 33 per cent of them had sufficient lipid to protect them temporarily while 40 per cent did not and in these 40 per cent the marginal increment of insecticide not absorbed by the reserve lipids was free to exert its lethal effect with a rate increased by the high temperature. But with the actual data at hand this suggestion may be regarded as no more than mildly plausible speculation.

Any theory to be considered must be able to compete with all other theories concerned with the same phenomena. Excretory and detoxificatory rates seem inadequate to fully explain negative temperature coefficients of toxic action of DDT (Vinson & Kearns 1952) and probably are inadequate to account for any of the more than 20 insecticides known to produce such negative coefficients. Vague generalizations about physiological rates and states (such as those in the preceding paragraph) while valuable as an incentive to research at present throw no light on the negative temperature coefficients. Thus other than the hypothesis advanced here there are really only two hypotheses: (1) the Hurst lipo-site of action equilibrium hypothesis which becomes engulfed in the present one and (2) the Fan-Cheng-Richards hypothesis of selective adsorption and concentration by chitin (Richards 1951). With regard to their hypothesis Richards states that it is highly speculative and does not account for the known resistance of certain arthropods. At the time the Fan-Cheng-Richards hypothesis was originated negative coefficients by insecticide injection had not been demonstrated and the hypothesis seemed more likely to represent the facts than it does now when ample evidence of such coefficients is available.

SUMMARY.—This paper presents an elucidation of an hypothesis regarding the role of insect lipids in insecticidal action and an examination of this hypothesis in the light of pertinent literature. This hypothesis in which the lipids act as a competitive site is sufficient to explain negative coefficients of toxic action with temperature and preconditioning effects of different temperatures. It seems to clarify the relationship between liposolubility and insecticidal action of compounds such as DDT analogues several of which are highly lipo-soluble yet have low grade insecticidal properties. To some extent this hypothesis may throw light on the varying resistances to a given insecticide of insects of different nutritional conditions, sexes, and stages of development; and perhaps, also, on seasonal, species and possibly strain variations in resistance. Of course it does not account for all such variations and should not be construed to do so.

The holding capacities of the total lipids of the American cockroach for DDT and methoxychlor at different temperatures are presented.

American cockroaches preconditioned at different temperatures seem to vary in their resistance to chlordane, bromine DDT, and fluorine DDT as they do to DDT. The order of toxicity for these three insecticides from the most toxic to the least range in the order: chlordane, DDT, bromine DDT, fluorine DDT. While female cockroaches are more resistant than males to the DDT type compounds no clear difference in resistance to chlordane was shown by the sexes. Adult *Drosophila* flies and *Oryzaephilus* beetles preconditioned at different temperatures also vary in their resistance to DDT thus extending

to five (with no exceptions) the number of species of insects which vary in their resistance to liposoluble insecticides when these are applied after adequate preconditioning. Chlordane, methoxychlor, fluorine DDT and bromine DDT when tested against *Oryzaephilus* beetles produces negative coefficients of action with temperature under proper conditions. Thus these may be added to the list of between 20 and 30 compounds which have been shown to produce such negative coefficients.

## LITERATURE CITED


Barron, E. S., Editor. 1952. Modern trends in physiology and biochemistry. Academic Press, New York.

Böhm, Otto. 1951. Über die Wirkung von *p-p*¹-Dichlorodiphenyl-trichloroethane (DDT) auf Insekten unter besonderer Berucksichtigung der Äbhangikeit der Kontaktgiftwirkung von Bau des insekten Integumentes. Pflanzenschutzberichte **7**: (3/4): 33–73.

Brown, A. W. A. 1951. Insect control by chemicals. John Wiley and Sons, New York.

Chadwick, L. E. 1952. The current status of physiological studies on DDT resistance. Amer. Jour. Trop. Med. and Hyg. **1**: 404–11.

Craufurd-Benson, H. J. 1938. An improved method for testing liquid contact insecticides in the laboratory. Bul. Ent. Res. **29**: 41–56.

Dresden, D., and B. J. Krijgsman. 1948. Experiments on the physiological action of contact insecticides. Bul. Ent. Res. **38**: 575–8.

Ellisor, L. O., and C. R. Blair. 1940. Effects of temperature upon toxicity of stomach poisons. JOUR. ECON. ENT. **33**: 760–2.

Gunther, F. A. 1945. Aspects of the chemistry of DDT. Jour. Chem. Ed. **22**: 238–42.

Guthrie, F. E. 1950. Effect of temperature on toxicity of certain organic insecticides. JOUR. ECON. ENT. **43**: 559–60.

Hoffman, R. A., and A. W. Lindquist. 1949. Effect of temperature on knockdown and mortality of house flies exposed to residues of several chlorinated hydrocarbon insecticides. JOUR. ECON. ENT. **42**: 891–3.

Hurst, H. 1949. Reversible Action of D.D.T. Nature **163**: 286–7.

Lindquist, A. W., A. H. Madden, H. O. Schroeder. 1945. Effect of temperature on knockdown and kill of house flies exposed to DDT. JOUR. ECON. ENT. **38**: 261–4.

Lindquist, A. W., A. R. Roth, W. W. Yates, R. A. Hoffman, and J. S. Butts. 195a. Use of radioactive tracers in studies of the penetration and metabolism of DDT in house flies. JOUR. ECON. ENT. **44**: 167–72. 1951b. The distribution of radioactive DDT in house flies. Ibid. **44**: 931–4.

Munson, S. C. 1953a. Some effects of storage at different temperatures on the lipids of the American roach and on the resistance of this insect to heat. JOUR. ECON. ENT. **46**: 657–66.
1953b. Some effects of storage at different temperatures on the resistance of the American roach to DDT. Ibid. **46**: 754–60.

Munson, S. C., and M. I. Gottlieb. 1953. The differences between male and female American roaches in total lipid content and in susceptibility to DDT. JOUR. ECON. ENT. **46**: 798–802.

Pearce, S. W., A. M. Mattson, W. J. Hayes, Jr. 1952. Examination of human fat for the presence of DDT. Science. **116**: 254–6.

Potter, C., and E. M. Gillham. 1946. Effects of atmospheric environment before and after treatment on the toxicity of contact poisons to insects. Ann. Appl. Biol. **33**: 142–9.

Pradhan, S., M. R. G. K. Nair, and S. Krishnaswami. 1952. Lipoid solubility as a factor in the toxicity of contact insecticides. Nature **170**: 619.

Reiser, R., D. S. Chadbourne, K. A. Kuiken, C. F. Rainwater, and E. E. Ivy. 1953. Variations in lipid content of the boll weevil and seasonal variation in its resistance to insecticides. JOUR. ECON. ENT. **46**: 337–40.

Richards, A. G. 1951. The integument of arthropods. U. Minn. Press. Minneapolis.

Sun, Y. P. 1947. An analysis of some factors affecting the results of fumigation tests on insects. Minn. Agr. Expt. Sta. Bul. **177**.

Vinson, E. B., and C. W. Kearns. 1952. Temperature and the action of DDT on the American roach. JOUR. ECON. ENT. **45**: 484–96.

Wilson, C. S. 1949. Piperonyl butoxide, piperonyl cyclonene, and pyrethrum applied to selected parts of individual flies. JOUR. ECON. ENT. **42**: 423–8.

Woodruff, Nancy. 1950. Interactions between temperature and toxicity of four insecticides applied by inspection. JOUR. ECON. ENT. **43**: 663–9.

# Parasites Affecting the Jack-Pine Budworm in Michigan

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The jack-pine budworm, *Choristoneura pinus* Free., has caused widespread destruction of jack pine throughout the Lake States periodically since 1923. The most severe outbreaks occurred during the early 1920's, the late 1930's, and early 1940's (Graham 1925, 1935; MacAloney 1944). Since 1949 severe defoliation of jack pine has occurred on the Huron National Forest and the Au Sable, Higgins Lake and Ogemaw State Forests in the lower peninsula, and on the Hiawatha National Forest in the upper peninsula. In 1951 and 1952 serious new infestations were observed on the Houghton Lake and Black Lake State Forests in the lower peninsula and in 1952 and 1953 in localized stands on the Lake Superior State Forest and Marquette National Forest in the upper peninsula.

Surveys were made to determine the extent of the budworm outbreak in Michigan in 1950 through 1953. Losses in merchantable and reproduction jack pine on the Huron National Forest have been reported (Benjamin 1952, 1953). Progress is reported herein on investigations of parasites of the jack-pine budworm begun during outbreaks on the Huron National Forest and adjacent State forests in the lower peninsula of Michigan in 1951, 1952, and 1953.

METHODS.—Periodic collections of the various jack-pine budworm stadia were made throughout the western one-third of the Huron National Forest and on adjacent State forests in the northcentral part of the lower peninsula. Collection stations in 1951 were located in jack-pine type approximately 200 feet from the road right-of-way, four each in jack pine sustaining heavy, medium, and light budworm defoliation in 1950. Collections in 1952 and 1953 were made at the same stations; defoliation was of medium intensity in 1952 and light in 1953 on all plots.

Field collections and rearings were made by workers at the Milwaukee (Wis.) laboratory of the Bureau of Entomology and Plant Quarantine. The dissections and identifications were handled at the New Haven (Conn.) laboratory in 1951 and at Milwaukee in 1952 and 1953.[1]

*Overwintering larvae.*—Six 15-inch twigs (two each from the upper crown, middle, and lower crown) plus two limbs ½- to ¾-inch in diameter constituted the individual samples collected at each station. These twigs were held in special rearing boxes equipped with collecting vials. Second-instar larvae, upon emerging from hibernation, entered the vials and were withdrawn daily. The larvae were preserved in 70-per cent alcohol.

*Mature larvae.*—One hundred mature budworm larvae were collected at each station when they were available. Pupation ranged from 0 to 29 per cent at the time of collection. Ten larvae obtained from each of 10 jack pines generally constituted a sample. After being held individually in glass vials for 24 hours to allow evacuation of the alimentary tract, the larvae were placed in KAAD solution.[2] Twenty-four hours later they were transferred to 70-per cent alcohol. Fifty mature larvae from each station were dissected.

*Pupae.*—One hundred jack-pine budworm pupae were collected at each station (10 from each of 10 trees). The pupae were held individually in No. 000 gelatin capsules for emergence of moths and adult parasites. Adult parasites were removed from the capsules and pinned or, in the case of small hymenopterons, were preserved in 70-per cent alcohol.

*Eggs.*—Originally it was planned to collect 25 egg masses at each station, felling one or more trees to obtain masses from the upper crown of dominant jack pine. Low egg populations prevented the attainment of this goal, but some eggs were collected at each station in 1951 and 1952. Single needles containing eggs were held in gelatin capsules for emergence of budworm larvae and parasite adults.

RESULTS.—*Trichogramma minutum* was the only egg parasite found during the study. Only one adult was reared from 12 egg collections in 1951. Failure to rear more was probably due to poor technique, as many eggs contained dead budworm

[1] The writers are indebted to V. M. Carolin, P. B. Dowden, and J. L. Bean for dissection and identification of material in 1951, and to L. C. Beckwith and H. G. Ewan for aid in the dissections in 1952.

[2] Kerosene 1 part, ethyl alcohol (95%) 7 to 10 parts, glacial acetic acid 2 parts, and dioxane 1 part.

**Table 1.—Per cent parasitization of the jack-pine budworm on the Huron National Forest and adjacent State Forests in Michigan.**

| STAGE OF HOST KILLED<br>PARASITE SPECIES | 1951 | | 1952 | | 1953 | |
|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | Average | Range |
| Egg masses: | (12)[1] | | (171) | | (None) | |
| *Trichogramma minutum* Riley | T | | 9 | 0–18 | | |
| Overwintering larvae: | (532) | | (386) | | (308) | |
| *Apanteles fumiferanae* Vier. | 22 | 2–44 | 7 | 0–36 | 10 | 0–21 |
| *Glypta fumiferanae* (Vier.) | 3 | 0– 8 | 7 | 0–22 | 3 | 0– 8 |
| Mature larvae: | (619) | | (591) | | (470) | |
| *Actia interrupta* Curr. | 1 | 0– 6 | 1 | 0– 6 | T | |
| *Agria affinis* (Fall.) | T | | 0 | | 0 | |
| *Lypha setifacies* (West.) | 3 | 0– 8 | 5 | 0–16 | 4 | 0–14 |
| *Phryxe pecosensis* T.T. | T | | T | | T | |
| Pupae: | (1200) | | (1051) | | (782) | |
| *Agria affinis* (Fall.) | T | | 2 | 0– 6 | 0 | |
| *Amblymerus verditer* (Nort.)[2] | T | | 2 | 0– 6 | 0 | |
| *Apechthis ontario* (Cress.) | T | | 0 | | T | |
| *Exochus* sp. | T | | T | | 0 | |
| *Habrocytus* sp.[2] | T | | T | | 0 | |
| *Itoplectis conquisitor* (Say) | 28 | 6–48 | 15 | 3–26 | 11 | 0–21 |
| *Phaeogenes hariolus* (Cress.) | T | | T | | T | |
| *Scambus hispae* (Harr.) | T | | 0 | | 0 | |
| *Syntomosphyrum* sp. (near *esurus* Riley) | | | T | | 0 | |
| Unidentified Diptera | T | | 0 | | 0 | |

[1] Numbers in parentheses refer to number of egg masses or individuals collected at 12 stations.
[2] Probably a secondary parasite.
T—Less than 1 per cent.

embryos. In 1952, 9 per cent of the budworm egg masses contained egg parasites (Table 1). In 1953, no collections were made because of the low budworm population.

*Apanteles fumiferanae* and *Glypta fumiferanae* were dissected from overwintering second-instar larvae. *Apanteles* was the more abundant in all plots in 1951 and 1953, attacking 22 and 10 per cent of the larvae, respectively. Parasitization by *Glypta* averaged 3 per cent in both years. In 1952 parasitization by these two species averaged 7 per cent.

Parasitization of mature larvae was limited to four species. *Lypha setifacies* was the most commonly encountered, constituting 3, 5, and 4 per cent in 1951, 1952, and 1953, respectively.

*Itoplectis conquisitor* was the most prevalent species reared from budworm pupae, accounting for 28, 15, and 11 per cent of the pupae in 1951, 1952, and 1953, respectively. The other nine species appeared to be of negligible importance.

Of the 15 species of parasites of the jack-pine budworm collected in Michigan, 5 were represented among 13 species reared from the budworm in Ontario (Walley 1953) (Table 2). *Itoplectis conquisitor* was abundant in both countries; *Phaeogenes hariolus* and *Scambus hispae* were abundant to common in Ontario; *Glypta fumiferanae* was abundant in Michigan; and *Apechthis ontario* was rare in both areas.

Of the parasites from Michigan, 13 were also in the list of parasites of the spruce budworm, *Choristoneura fumiferanae*, from New York (Dowden *et al.* 1948, Dowden & Carolin 1948) and Maine (Jaynes & Drooz 1952), and six were parasites of a form of the budworm reared from Douglas-fir in Colorado (Dowden *et al.* 1948).

*Apanteles fumiferanae* was abundant in Michigan and also in New York, Maine, and Colorado. *Glypta fumiferanae*, abundant in Michigan in 1952 and common in 1951 and 1953, was also abundant in New York in 1946 and 1947 but declined in numbers in 1948. It was commonly encountered in Maine from 1948 through 1951, and was abundant in Colorado in 1945. *Itoplectis conquisitor*, the most abundant pupal parasite in Michigan, was abundant in New York in 1946 and 1947 and declined in numbers in 1948. In Maine it was common in 1948, and declined to a trace in 1950 and 1951. It was rare in Colorado in 1945. The egg parasite, *Trichogramma minutum*, was

**Table 2.—Abundance of parasites of the jack-pine budworm collected in Michigan and Ontario compared with those from the spruce budworm in New York and Maine, and a budworm from Douglas-fir in Colorado.**

| | Jack-Pine Budworm | | | | Douglas-Fir | Spruce Budworm | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Michigan | | | Ontario | Colorado | New York | | | Maine | | | |
| Parasite | 1951 | 1952 | 1953 | 1951 | 1945 | 1946 | 1947 | 1948 | 1948 | 1949 | 1950 | 1951 |
| Hymenoptera | | | | | | | | | | | | |
| Ichneumonidae | | | | | | | | | | | | |
| *Apechthis ontario* (Cress.) | T[1] | O | T | R | O | A | A | A | C | A | A | A |
| *Exochus* sp. | T | T | O | O | O | R | R | R | A | R | R | R |
| *Glypta fumiferanae* (Vier.) | C | A | C | R | A | A | A | C | C | C | C | C |
| *Itoplectis conquisitor* (Say) | A | A | A | A | R | A | A | C | C | R | T | T |
| *Phaeogenes hariolus* (Cress.) | T | T | T | A | A | O | T | C | R | C | A | A |
| *Scambus hispae* (Harris) | T | O | O | C | O | T | T | T | T | T | T | T |
| Braconidae | | | | | | | | | | | | |
| *Apanteles fumiferanae* Vier. | A | A | A | O | A | A | A | A | A | A | A | A |
| Chalcidoidea | | | | | | | | | | | | |
| *Amblymerus verditer* (Nort.) | R | R | O | O | C | A | C | C | O | C | C | C |
| *Trichogramma minutum* (Riley) | T | A | | O | O | A | R | T | A | A | A | C |
| *Habrocytus* sp. | T | T | O | O | O | O | O | O | O | O | O | O |
| *Syntomosphyrum* sp. (near *esurus* Riley) | T | T | O | O | O | O | O | O | O | O | O | O |
| Diptera | | | | | | | | | | | | |
| Larvaevoridae | | | | | | | | | | | | |
| *Actia interrupta* Curr. | R | R | T | O | R | R | R | R | A | C | C | C |
| *Lypha setifacies* (West.) | C | C | C | O | O | O | T | A | O | R | C | A |
| *Phryxe pecosensis* T. T. | T | O | T | O | O | A | A | A | R | A | C | C |
| Sarcophagidae | | | | | | | | | | | | |
| *Agria affinis* (Fall.) | T | O | O | O | O | C | C | O | C | C | R | C |

[1] Letters refer to abundance of parasites as follows:
A (abundant)—Over 5 per cent of budworm parasitized.
R (rare)—occasionally reared in small numbers.
O (none)—none reared.
C (common)—reared in small numbers at most points.
T (trace)—less than 1 per cent.

abundant in Michigan in 1952; no collections were made in 1953. After being abundant in New York in 1946, it declined rapidly to a very low level. In Maine this species remained abundant for 3 years and then declined.

*Intensity of Budworm Populations.*—Jack-pine budworm populations on the Huron National Forest and adjacent State forests reached a peak in 1951 and then declined markedly. Defoliation was of medium intensity in all jack-pine stands in the sampled areas in 1951, light in 1952, and from none to light in 1953. Budworm populations were essentially the same on all areas.

CONCLUSIONS.—It is too early to draw any conclusions concerning the role of parasites in the jack-pine budworm gradation in central Michigan. However, comparison of the species reared or dissected from the various stadia with those in Ontario, and with the parasites of the spruce budworm in New England and of a budworm variety in Colorado, indicates that some of the more important parasite species are widely distributed on several species or varieties of budworms. Of these species, *Itoplectis conquisitor* and *Apanteles fumiferanae* appear to be of importance in reducing budworm populations.

## LITERATURE CITED

**Benjamin. D. M.** 1952. The jack-pine budworm, a menace to Michigan jack pine. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note **376,**

**Benjamin, D. M.** 1953. The jack-pine budworm in Michigan. U. S. Forest Serv., Lake States Forest Expt. Sta. ,Tech. Note **396.**

**Dowden, P. B.,** W. D. Buchanan, and V. M. Carolin. 1948. Natural control factors affecting the spruce budworm. JOUR. ECON. ENT. **41**(3): 457–64.

**Dowden, P. B.,** and V. M. Carolin. 1948. Natural control factors affecting the spruce budworm in the Adirondacks during 1946–1948. JOUR. ECON. ENT. **43**(6): 774–83.

**Graham, S. A.** 1925. Two dangerous defoliators of jack pine. JOUR. ECON. ENT. **18**(2): 337–43.

**Graham, S. A.** 1935. The spruce budworm on Michigan pine. Univ. Mich. School Forestry and Conserv. Bul. **6.**

**Jaynes, H. A.,** and A. T. Drooz. 1952. The importance of parasites in the spruce budworm infestations in New York and Maine. JOUR. ECON. ENT. **45**(6): 1057–61.

MacAloney, H. J. 1944. Relation of root condition, weather, and insects to the management of jack pine. Jour. Forestry 42(2): 124–9.
Walley, G. S. 1953. Hymenopterous parasites of *Choristoneura pinus* Free. (Lepidoptera: Tortricidae) in Canada. Canad. Ent. 85(4): 152.

# Argentine Ant Control with Sprays and Bait in Two California Lemon Groves[1]

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The Argentine ant, *Iridomyrmex humilis* Mayr, was first found in California at Ontario, San Bernardino County, in 1905. Since then it has spread until it is generally distributed throughout California and is an important pest in southern California citrus groves, homes, and gardens. Many methods of Argentine ant control have been developed in the past, but few of them have proved entirely satisfactory.

In 1910, Newell & Barber (1913) conducted tests with various types of poisoned baits (syrups) for ant control. From 1912 to 1915, Barber (1916) experimented with glass bottles, metal cans, and small waxed-paper bags as poisoned-bait containers. In 1920, A. F. Swain, working at Riverside, California, tried paper bags as a replacement for the more expensive metal cans (2-ounce spice cans). These were later discarded in favor of small pressed-paper cups. As late as 1924, 1- and 2-ounce spice cans were still used. William J. Rabe of Redlands, California, in 1942, patented a small metal clip designed to hold a small, fluted metal bottle cap of poisoned bait on the tree trunk. At present a small, lidded waxed-paper cup which holds 1 ounce of poisoned syrup is being produced commercially and is commonly used.

In tests by Gerhardt (1953), dieldrin, chlordane, and heptachlor were found to give control of Argentine ants for at least 6 months when applied as sprays in citrus groves. In view of the results obtained in these earlier tests, it seemed advisable to conduct experiments in which the effectiveness of these spray materials might be compared with that of poisoned bait in commercially available waxed-paper cups.

MATERIALS AND METHODS.—Experiments were conducted in two groves of lemon trees in Santa Barbara County that were heavily infested with ants. Each plot consisted of a block of 25 trees. Plots were replicated at random three times for each treatment. Data were taken from the inner block of nine trees in each replicate.

In these experiments chlordane and dieldrin were used as wettable powder sprays, and heptachlor was used as an emulsifiable spray, all at a dosage of 2 pounds of active ingredient per 100 gallons water. Sprays were applied with a regular hand-type spray gun at the rate of 1.5 to 3 gallons per tree, and covered the skirt and trunk of the tree as well as the litter beneath (Gerhardt 1951).

In bait tests a small waxed-paper cup containing approximately 1 ounce of a 0.3 per cent arsenic-poisoned syrup[3] was placed at the base of the trunk of each tree.

Trees in the experimental plot were checked for ants once a month for the first 2 months following treatment, and every second month thereafter. At checking time all poisoned-bait cups missing, empty, or less than one-fourth full were replaced.

RESULTS.—*Grove No. 1.*—Results of spray and bait tests in grove No. 1 are given in table 1. In this test all the trees in the poisoned-bait plots were still infested 2 months after treatment, but by the third month infested trees had dropped to 47.9 per cent. The dieldrin and heptachlor plots were free of ants at this time, and the chlordane plot had only 3.1 per cent ant-infested trees. Ten

[1] Paper No. 801, University of California Citrus Experiment Station, Riverside, California.

[2] Marcus E. Cravens, Deputy Agricultural Commissioner of Santa Barbara County, arranged for the experimental plots, and John D. Paschke of the Department of Entomology, University of California Citrus Experiment Station, Riverside, assisted in applying the treatments and making the counts.

[3] Cups of syrup supplied by the Johnson Ant Control Company, Walnut Creek, California. Syrup contained 0.3 per cent sodium arsenite (in water-soluble form, expressed as 0.13 per cent metallic).

**Table 1.—Effectiveness of various treatments against the Argentine ant on lemon trees at different periods after application. 1951–52.**

| Material[1] | Percentage of Trees Infested with Ants After Treatment[2] (Months) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| *Grove No. 1* (treated June 7; first check, July 18) | | | | | | | | | | |
| Chlordane, 50% W.P. | 0.0 | 0.0 | 3.1 | — | 0.0 | — | 3.1 | — | 0.0 | — |
| Dieldrin, 25% W.P. | 3.8 | 0.0 | 0.0 | — | 0.0 | — | 4.2 | — | 0.0 | — |
| Heptachlor, 25% emul. | 12.9 | 25.8 | 0.0 | — | 0.0 | — | 9.8 | — | 16.1 | — |
| Poisoned bait[3] | 100 | 100 | 47.9 | — | 59.4 | — | 75.5 | — | 41.1 | — |
| Check | 100 | 100 | 100 | — | 81.8 | — | 100 | — | 100 | — |
| *Grove No. 2* (treated October 10; first check, November 11) | | | | | | | | | | |
| Chlordane, 50% W.P. | 4.1 | 0.0 | — | 4.0 | — | 12.5 | — | 22.0 | — | 37.5 |
| Dieldrin, 25% W.P. | 4.8 | 0.0 | — | 4.8 | — | 0.0 | — | 0.0 | — | 8.5 |
| Heptachlor, 25% emul. | 0.0 | 3.7 | — | 3.7 | — | 0.0 | — | 3.7 | — | 24.7 |
| Poisoned bait[3] | 92.6 | 44.4 | — | 18.5 | — | 37.0 | — | 22.2 | — | 55.5 |
| Check | 100 | 100 | — | 70.4 | — | 55.6 | — | 92.6 | — | 100 |

[1] Dosage, 2 pounds active ingredient per 100 gallons of water, unless otherwise specified.
[2] All trees were infested before treatment.
[3] Syrup containing 0.3 per cent sodium arsenite; 1 ounce per tree in paper cup.

months after treatment, trees in the dieldrin and chlordane plots were free of ants, but 16.1 per cent of the trees in the heptachlor plots, and 41.1 per cent of those in the poisoned-bait plots, were infested. During this time poisoned-bait cups were replaced on an average of three times for each tree.

*Grove No. 2.*—Results of similar spray and poisoned-bait tests in a second grove are also given in table 1. Heptachlor-treated plots were free of ants 1 month after treatment, while the plots receiving chlordane or dieldrin spray had less than 5 per cent infested trees. Plots containing poisoned-bait cups were 92.6 per cent infested at this time. Two months after treatment, infested trees in the poisoned-bait plots had dropped to 44.4 per cent, trees in the heptachlor-treated plots were 3.7 per cent infested, and the chlordane and dieldrin plots were free of ants. All the trees in the check plots were infested.

The bait treatment reached its maximum effectiveness in 5 months after treatment, when 18.5 per cent of the trees were infested. At this time less than 5.0 per cent of the trees in the spray-treated plots were infested. Reinfestation of all plots increased from then on. Eleven months after treatment, 55.5 per cent of the trees in the poisoned-bait plots were infested, as compared with 8.5 per cent in the dieldrin plots, 37.5 per cent in the chlordane plots, and 24.7 per cent in the heptachlor plots. The percentage of ant-infested trees in the check plots dropped during the fifth to seventh months, but by the eleventh month all trees were again infested.

Summary.—Sprays and poisoned-bait cups were applied to replicated blocks of lemon trees in two groves in Santa Barbara County, California, for control of the Argentine ant.

When poisoned-bait cups were placed beneath trees heavily infested with ants, they did not bring about a reduction in ant infestation until 2 months later. On the other hand, one application of a spray containing 2 pounds of chlordane, dieldrin, or heptachlor per 100 gallons of water, applied at the rate of 1.5 to 3 gallons of spray per tree in the suggested manner, controlled Argentine ants on lemon trees for at least 6 months.

Of the three materials applied as sprays to lemon trees in the two groves, dieldrin gave better control than did chlordane or heptachlor.

During the 11 months that this experiment was in progress, it was found necessary to replace the poisoned-bait cups on an average of three times for each tree.

More time and labor were involved in servicing and maintaining poisoned-bait cups in the experimental plots than were required to apply sprays for ant control. Eleven months after treatment 55.5 per cent of the trees in the poisoned-bait plots were infested with ants, while only 8.5 per cent of the trees in the dieldrin-sprayed plots, 37.5 per cent in the chlordane-sprayed plots, and 24.7 per cent in the heptachlor-sprayed plots were infested.

## Literature Cited

**Barber, Ernest R.** 1916. The Argentine ant: Distribution and control in the United States. U. S. Dept. Agr. Bul. 377: 1–23.

Gerhardt, Paul D. 1951. Control of the Argentine ant in citrus orchards. Univ. Calif. Citrus Expt. Sta., Dept. Ent. News Letter No. 53.
Gerhardt, Paul D. 1953. Studies with chlordane, dieldrin, aldrin, and heptachlor for control of the Argentine ant in California citrus orchards. JOUR. ECON. ENT. 46: 1063–6.
Newell, Wilmon, and T. C. Barber. 1913. The Argentine ant. U. S. Dept. Agr. Bur. Ent. Bul. 122: 1–98.
Swain, A. F. 1920. Argentine ant control from an economic standpoint. Calif. Dept. Agr., Monthly Bul. 9(8): 333–8.

# Chemical Control of a Spider Mite on Wheat in Eastern New Mexico[1]

T. L. HARVEY[2,3]

The tetranychid mite, *Paratetranychus pratensis*, was originally described at Pullman, Washington from timothy, *Phleum pratense*, by Banks (1912). Ewing (1913) and McGregor (1919, 1950) published revised descriptions, but apparently no additional data have been published since that time. However, in recent years this mite has been considered as a pest of grasses in Washington. In 1952, it was collected on wheat in Kansas.[4] This mite appeared to be the most injurious pest to the 1952–1953 wheat crop in eastern New Mexico. It was present on wheat from the time of the first survey in September until the crop was mature in July. During the fall, when most of the wheat was in the two- to five-leaf stage, the mites were commonly located in small colonies on the leaves. Part of the leaf areas occupied by the mite colonies were often dead and characteristically colored brown or yellow. During the winter months, after the plants had tillered and temperatures became lower, the mites were found mainly in the crown of the plants near the soil surface. Infested plants could be detected by the presence of webbing in the crowns and the abnormal number of dead leaves. Some heavily-infested plants were killed by a combination of mite feeding and insufficient moisture. The mites usually remained at the bases of the plants until sometime in May, when they began moving to the upper leaves and heads, apparently in search of more succulent feeding. At that time, the edges of infested leaves were discolored and curled inward around the mites. In some fields, the heads became infested as they emerged from the boot (Fig. 1).

Wheat plants grown in the laboratory which were heavily infested when they reached the two-leaf stage were killed within 3 weeks, while uninfested plants grown under the same conditions remained healthy.

The heavy mite population which occurred on wheat plants afforded a good opportunity for a study of chemical control measures. Four separate tests, made from April through June, 1953, are summarized and discussed in this paper.

MATERIALS AND METHODS.—The 14 different chemicals, listed in tables 1 to 4, were tested in four separate experiments. Several of the sprays were applied at more than one rate. The chemicals used included seven organic phosphates, two sulphonates, two chlorinated hydrocarbons, and one each of a sulfone, sulfite and a carbinol. These materials were applied as emulsions with a power sprayer designed for small plot use. The unit consisted of a boom equipped with cone-type nozzles and a small twin-cylinder pump with a separate power unit. Each spray material was mixed in and pumped from a separate 5-gallon glass bottle. The sprayer was mounted on a garden tractor with a speed of 2.75 miles per hour.

The mite populations were normally enclosed in masses of webbing, soil particles, and curled leaves. As it was impractical to make mite counts direct from the wheat plants, a method was developed whereby a percentage of the mites collec-

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[3] The author wishes to thank all those who cooperated in these studies; to acknowledge that determinations of mites were made by E. W. Baker, BE&PQ, E. A. McGregor, BE&PQ (retired) and A. E. Pritchard, University of California; and to express appreciation to the chemical companies and corporations which supplied the materials used.

[4] This information was kindly supplied by C. F. Henderson of the U.S.D.A. and E. W. Tilton, Kansas State College, Garden City Branch Station, Garden City, Kansas, in a report submitted by Dr. R. G. Dahms of the U.S.D.A

FIG. 1.—Part of a wheat head infested with mites. Egg is visible near center of mite colony. Enlarged about 20 times.

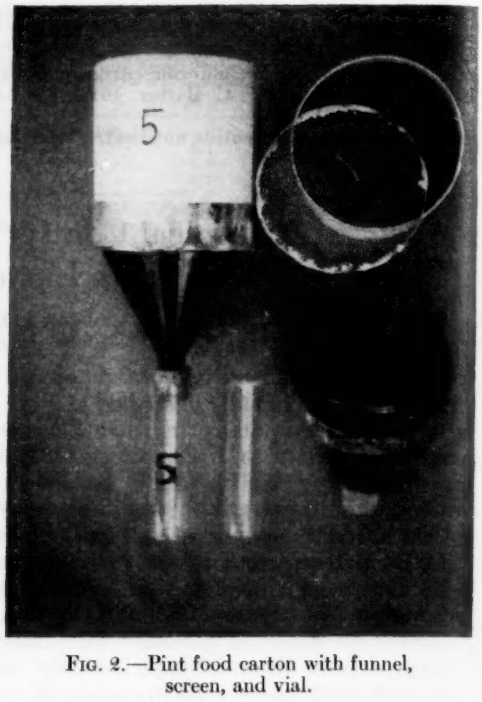


FIG. 2.—Pint food carton with funnel, screen, and vial.

ted on a plant sample were separated from the plant material by centrifuging. The plant samples which were used to evaluate the mite populations were collected in pint-carton food containers. Different parts of the wheat plants were sampled for the different experiments, because of the movement of the mites on the plants as already described. For experiments 1 and 2, the crowns of three wheat plants or that part just below and 2 inches above the soil surface were sampled. In experiment 3, 20 wheat heads and culms from 2 inches above the soil surface were collected, and in experiment 4 the sample consisted of 10 wheat heads and the flag leaves. About 24 hours after the samples were collected in the field and transported to the laboratory, the lids were removed from the pint cartons containing the samples and replaced by funnels fitted with screens and vials as illustrated in figure 2. These units were then placed in the containers attached to the arms on the wheel of the centrifuge (Fig. 3). A 1-horsepower electric motor drove the wheel by means of V-belt and pulleys at approximately 500 revolutions per minute. In these tests, a centrifugal force of about 170 times gravity was applied for two 1-minute intervals, with a 1-minute pause between each period of centrifuging. All active stages of living mites which were captured in the vials were then counted under a

FIG. 3.—Centrifuge made from automobile wheel and axle. Electric motor is located behind wheel.

**Table 1.—Mites collected from the crowns of three plants and per cent control following treatment.**

| | Materials | 5 Days Following Treatments | | 18 Days Following Treatments | |
|---|---|---|---|---|---|
| | Pounds of Active Ingredient per Acre | Average Number[1] | Per Cent Control | Average Number[1] | Per Cent Control |
| Systox | 0.5 | 43.0 | 73.2 | 25.3 | 64.4 |
| *Ovotran* | 3.2 | 42.0 | 73.8 | 25.3 | 64.4 |
| Parathion | 0.5 | 68.8 | 57.1 | 28.2 | 60.3 |
| Schradan | 1.0 | 81.7 | 49.0 | 30.3 | 57.3 |
| Compound 923 | 9.6 | 57.8 | 63.9 | 31.2 | 56.0 |
| R-242 | 2.0 | 95.6 | 40.4 | 33.8 | 52.4 |
| Metacide | 0.6 | 78.7 | 51.0 | 39.0 | 45.1 |
| Malathion | 2.0 | 47.3 | 70.5 | 47.0 | 33.8 |
| Aramite | 0.6 | 90.5 | 43.5 | 50.0 | 29.6 |
| *Chlorobenzilate* | 1.3 | 87.6 | 45.3 | 50.2 | 29.3 |
| EPN | 0.5 | 62.0 | 61.3 | 54.0 | 25.9 |
| Methyl parathion | 0.5 | 82.5 | 48.5 | 88.3 | — |
| Check | | 160.3 | | 71.0 | |
| L.S.D. at .05 level | | 43.6 | | 30.9 | |

[1] The average numbers for six replications which are given represent approximately one-tenth of the total number of mites present on the samples. Average maximum and minimum temperatures were 73° and 38° F., respectively, from April 19 to May 7, 1953 inclusive.

microscope. The percentage of mites removed from the samples by such centrifuging was approximately 10 per cent of the total number of mites which could be removed by prolonged and repeated centrifuging. After repeated centrifuging failed to remove mites from the samples, no mites could be detected when the samples were examined under a microscope. Factors which influenced the percentage of the mites removed were the amount of centrifugal force applied, length of time the force was applied, time interval between collection of the sample and centrifuging, and the characteristics of the plant sample such as the amount of material or part of the plant being centrifuged. The

**Table 2.—Mites collected from the crowns of three plants and per cent control following treatment.**

| | Materials | 5 Days Following Treatments | | 18 Days Following Treatments | |
|---|---|---|---|---|---|
| | Pounds of Active Ingredient per Acre | Average Number[1] | Per Cent Control | Average Number[1] | Per Cent Control |
| Parathion | 2.0 | 12.3 | 86.7 | 6.3 | 84.8 |
| Parathion | 0.5 | 29.6 | 68.0 | 17.1 | 58.8 |
| Systox | 0.5 | 19.1 | 79.4 | 20.6 | 59.4 |
| Malathion | 1.0 | 55.3 | 40.3 | 22.3 | 40.3 |
| *Ovotran* | 3.2 | 70.5 | 23.9 | 25.3 | 39.0 |
| DMC | 1.1 | 58.5 | 36.8 | 37.0 | 10.8 |
| Schradan | 1.0 | 75.0 | 19.0 | 37.3 | 10.1 |
| Compound 923 | 9.6 | 52.6 | 43.2 | 39.5 | 4.8 |
| Check | | 92.6 | | 41.5 | |
| L.S.D. at .05 level | | 39.2 | | 17.4 | |

[1] The average numbers for six replications which are given represent approximately one-tenth of the total number of mites present on the samples. Average maximum and minimum temperatures were 81° and 44° F., respectively, from May 6 to May 24, 1953 inclusive.

**Table 3.—Mites collected from 20 wheat heads and culms and per cent control following treatments.**

| | Materials | 7 Days Following Treatments | |
|---|---|---|---|
| | Pounds of Active Ingredient per Acre | Average Number[1] | Per Cent Control |
| Systox | 1.0 | 31.0 | 85.7 |
| Parathion | 1.0 | 33.8 | 84.4 |
| *Chlorobenzilate* | 2.7 | 36.5 | 83.2 |
| EPN | 1.0 | 66.0 | 69.6 |
| *Ovotran* | 3.2 | 74.5 | 65.7 |
| Compound 923 | 9.6 | 102.6 | 52.8 |
| R-242 | 4.0 | 103.6 | 52.4 |
| Metacide | 1.0 | 123.0 | 43.4 |
| Malathion | 3.0 | 151.1 | 29.6 |
| Dieldrin | 1.0 | 295.0 | — |
| Check | | 217.5 | |
| L.S.D. at .05 level | | 51.2 | |

[1] The average numbers for six replications which are given represent approximately one-tenth of the total number of mites present on the samples. Average maximum and minimum temperatures were 91° and 54° F., respectively, from May 26 to June 3, 1953 inclusive.

method required about 1 minute per sample for processing, exclusive of actual counting. It had the advantage of giving some check on the presence of predatory mites, thrips, and other insects small enough to pass through the 18-mesh screen used in the apparatus.

The plots were arranged in randomized blocks and each treatment was replicated six times. The plot size was 21 by 100 feet or approximately 1/20 acre. The actual area sprayed was a swath 15 feet wide

**Table 4.—Mites collected from 10 wheat heads and flag leaves and per cent control following treatments.**

| | Materials | 3 Days Following Treatments | | 5 Days Following Treatments | |
|---|---|---|---|---|---|
| | Pounds of Active Ingredient per Acre | Average Number[1] | Per Cent Control | Average Number[1] | Per Cent Control |
| Parathion | 1.0 | 48.6 | 69.2 | 13.0 | 88.7 |
| Systox | 1.0 | 52.5 | 66.7 | 29.6 | 74.4 |
| Systox | 0.5 | 73.0 | 53.7 | 30.1 | 73.9 |
| Parathion | 0.5 | 82.3 | 48.0 | 31.1 | 73.1 |
| *Chlorobenzilate* | 2.7 | 80.6 | 48.9 | 35.0 | 69.7 |
| Parathion | 0.25 | 83.1 | 47.3 | 40.3 | 65.1 |
| Methyl parathion | 1.0 | 99.8 | 36.7 | 42.1 | 63.5 |
| Systox | 0.25 | 98.8 | 37.4 | 47.5 | 58.9 |
| EPN | 1.0 | 81.0 | 48.7 | 57.1 | 50.6 |
| *Ovotran* | 3.2 | 105.0 | 33.5 | 61.6 | 46.7 |
| DMC | 1.1 | 80.8 | 48.8 | 62.1 | 46.2 |
| Aramite | 1.0 | 157.6 | — | 76.0 | 34.2 |
| Dieldrin | 1.0 | 139.3 | 11.7 | 190.1 | — |
| Check | | 157.8 | | 115.5 | |
| L.S.D. at .05 level | | 39.1 | | 33.3 | |

[1] The average numbers for six replications which are given represent approximately one-tenth of the total number of mites present on the samples. Average maximum and minimum temperatures were 93° and 56° F., respectively, from June 5 to June 10, 1953 inclusive.

lengthwise down the center of each plot, leaving a strip of untreated plants about 6 feet wide along the sides of each plot. The turnways at the ends of all plots were also untreated, to help minimize the influence of mite movement between plots. Precipitation was light throughout the period, not more than 0.5 inch of rainfall during the course of any one experiment. Average maximum and minimum temperatures for the duration of each experiment are given in the tables. The percentages of mortality were calculated by Abbott's formula. Seventy-five per cent mortality or better was used as the criterion for regarding a material to be adequately effective. The population data and the least significant difference between treatment populations at the .05 level are also given in the tables.

RESULTS.—Experiment 1 included 12 materials which are listed in table 1. The sprays were applied with 60 pounds pressure at a rate of 8 gallons per acre. The average initial population for the 84 plots was 176.3 mites per three-plant sample. The pretreatment population data were analyzed in the same manner as the data taken after treatment. Pretreatment differences between the treated plots were not statistically significant. Spray applications were made April 19 at the rates shown in table 1. Post-treatment infestation records were made on the 5th and 18th days following treatment. Systox, *ovotran*, and malathion gave approximately 75 per cent mortality on the fifth day following treatment. None of the materials tested were adequately effective after 18 days, Systox and *Ovotran* gave the best results with parathion ranking third.

Experiment 2 included the testing of seven materials which are listed in table 2. The sprays were applied with 40 pounds pressure at a rate of 10 gallons per acre. The average initial population for the 54 plots was 60.8 mites per three-plant sample. Pretreatment population differences between the treated plots were not statistically significant. Spray applications were made on May 6 at the rates shown in table 2. Post-treatment infestation records were made on the 5th and 18th days following treatment. Parathion at 2 pounds per acre produced 87 and 85 per cent mortality on the 5th and 18th days following treatment. Systox at 0.5 pound per acre produced 79 per cent mortality on the 5th day, but it was not adequately effective 18 days following treatment.

Experiment 3 included the testing of 10 materials which are listed in table 3. The sprays were applied with 60 pounds pressure at a rate of 8 gallons per acre. The average initial population for the 66 plots was 160.6 mites per 20 heads and culms. Pretreatment differences between the treatment plots were not statistically significant. Spray applications were made on May 26 at the rates given in table 3. A post-treatment infestation record was made 7 days after treatment. Systox, parathion and *Chlorobenzilate*[5] produced 86, 84 and 83 per cent mortality, respectively. EPN approached the level of effectiveness desired, giving 70 per cent mortality. All four of these materials were used at twice the rates at which they were used in experiment 1. The mite population in the dieldrin-treated plots was significantly higher than the population in the checks.

Experiment 4 included the testing of nine materials which are listed in table 4. The sprays were applied with 60 pounds pressure at a rate of 8 gallons per acre. The infestation records were taken from samples composed of 10 wheat heads and the flag leaves. The initial population appeared to be sufficiently uniform to disregard making pretreatment counts for each plot. Spray applications were made on June 5 at the rates given in table 4. Post-treatment infestation records were made on the 3rd and 5th day following treatment. None of the treatments were adequately effective after 3 days, although parathion at 1 pound per acre produced the highest mortality. On the 5th day following treatment, parathion at the 1-pound rate remained the best with 89 per cent mortality. Systox at 1 pound and at 0.5 pound, parathion at 0.5 pound, and *Chlorobenzilate* approached the desired effectiveness with 74, 74, 73, and 70 per cent mortality respectively. The mite population in the dieldrin treated plots was significantly higher than the population in the checks 5 days after treatment. Populations of the predatory thrips *Scolothrips sexmaculatus* (Perg.) appeared to be low in the plots which were treated with dieldrin.

DISCUSSION.—Systox and parathion consistently gave the best control among

[5] 4, 4'-dichlorobenzilic acid ethyl ester.

the materials tested and were the only materials with the exception of *Chlorobenzilate*, which gave erratic results, to produce more than 75 per cent mortality. *Ovotran*, malathion, and EPN approached a level of being adequately effective in one experiment and were less effective in others. The temperature variation for each experiment may have contributed to the inconsistency of these materials. The following chemicals produced mortalities of less than 75 per cent in all of the experiments in which they were tested at the time population records were made: *Ovo*tran, malathion, EPN, schradan, compound 923, Metacide, methyl parathion, R-242, Aramite, DMC, and dieldrin. In experiments 3 and 4, the mite pupulations became significantly higher in the plots treated with dieldrin than in the check plots. The explanation for this may be that dieldrin reduced the population of predatory thrips, *Scholothrips sexmaculatus*, while producing little if any mortality among the mites.

SUMMARY.—The mite, *Paratetranychus pratensis* appeared to be the most injurious pest on wheat in eastern New Mexico in 1952–53. Mite populations were recorded by centrifuging. Of the 14 different chemicals tested, Systox and parathion consistently gave the best control. *Chlorobenzilate* gave erratic results. *Ovotran*, malathion, EPN, schradan, Metacide, methyl parathion, R-242, Aramite, DMC, compound 923, and dieldrin produced less than 75 per cent mortality in these tests. The possible importance of the predator, *Scolothrips sexmaculatus*, was indicated when mite populations in the plots treated with dieldrin became significantly higher than in the check plots.

## LITERATURE CITED

**Banks, Nathan.** 1912. New American mites. Proc. Ent. Soc. Wash. **14:** 97–8.
**Ewing, H. E.** 1913. Taxonomic characters in *Tetranychus*. Ann. Ent. Soc. Am. **6:** 459.
**McGregor, E. A.** 1920. Red spiders of America. Proc. U. S. Natl. Mus. **56** (2303): 668–9.
**McGregor, E. A.** 1950. Mites of the family Tetranychidae. Amer. Midland Naturalist. **44:** 350.

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# Seed Treatment of Fall Planted Wheat for Wireworm Control[1]

ELLSWORTH HASTINGS and T. E. COWAN[2]

Each spring for the past few years numerous reports of apparent "winter-kill" have been received from winter wheat growing areas of Central Montana. Considerable reseeding to spring wheat has been necessary in the more heavily damaged spots, and where the stands were thin, but not reseeded, reduced yields were obtained. Upon investigation the damaged areas were found to be infested with wireworms in sufficient numbers to account for much of the trouble which had previously been considered "winter-kill." Fifty-three beetle larvae collected from the Denton, Montana, area were sent to the Division of Insect Detection and Identification of the Agricultural Research Service, Washington, D. C., for identification. Forty-nine were found to belong to the family Elateridae, 48 of which were "probably *Athous sp.*" and one was determined as *Limonius sp.* The remaining four larvae belonged to the family Tenebrionidae and were identified as "probably *Eleodes sp.*"

Since A. P. Arnason and his co-workers demonstrated the effectiveness of seed treatment with lindane for wireworm control in spring wheat in the Canadian provinces, many insecticides have been tested for their efficacy in wireworm control. Several of these insecticides in combination with organic mercurial compounds for smut control have proven very effective in seed treatment for spring-planted crops. However, the problem of wireworm damage to fall-planted grain had received no attention until tests were planned in

PAID PAPER.
[1] Contribution from Montana State College, Agricultural Experiment Station, Project No. M.S. 38, Paper No. 333 Journal Series.
[2] Chipman Chemical Co., Billings, Montana.

Central Montana in the fall of 1951.

Two blocks of farm land, both of which had histories of wireworm damage, were obtained for experimental purposes. These two fields, located north of Denton, Montana, were typical relative to the soil, topography, and cropping practices of this extensive winter wheat growing area, i.e., sandy loam soil, gently rolling topography, and alternate years of cropping and summer fallow. No insecticidal treatment for wireworm control had ever been applied in this area. A seeding rate of 1.25 bu. per acre is the common practice in this area and this rate was used in the tests.

Both of the fields were divided into plots of approximately 6 acres each and all plots were planted with Yogo wheat on Sept. 19, 1951. The seed wheat, with the exception of that to be seeded in the check plots, was treated with a slurry of *Mergamma*, a mixture of 40 per cent gamma isomer of benzene hexachloride and 2 per cent phenyl mercury urea, and the seed for the check plots was treated with ceresan M only. All seed was treated and sacked the day before planting. No attempt was made to determine quantitatively the wireworm population in these fields. However, at the time of seeding wireworms could be readily encountered in the first few inches of soil and were often turned up by the drill which was set for 4-inch depth of planting at which depth the soil was moist.

Germination and growth were rapid and observations made the first week in November showed good stooling and no obvious differences in plant cover between the check plots and treated plots. Visual inspections were made again early in the spring, on April 14. There were still no visible differences between checks and treated plots in either field.

The plots were visited again on May 12 at which time visible differences in plant cover were noted between the check plots and treated plots in field No. 1. Many dead plants were in evidence on the untreated check plots of this field, and several live wireworms per plant could be obtained in the more heavily damaged areas.

Wheat plants were dug in the treated plots on May 12 and the root areas inspected. Numerous dead wireworms were found on the plots treated with 2.25 and 2.50 ounces of *Mergamma* per bushel of

FIG. 1.—The wheat in the foreground was untreated and the background was treated for control of wireworms.

seed while in plots treated with 1.75 and 2.00 ounces per acre very few dead larvae were seen. The dead wireworms were found adjacent to the remains of the germinated seed and they had the appearance of having died only a short time before they were found. In no case were live wireworms found in the immediate vicinity of the rootlets or crowns of the growing plants. The plants in the treated plots where dead wireworms were found near the seed remains did not appear to be as thrifty as other plants which were free from worms. However, later observations indicated that these plants recovered at least to a very large extent.

The vegetative cover on all plots of field No. 2 still appeared to be uniform on visual inspection on the May 12th date. On June 2 another check was made of the various plots in the two fields. At this time visible differences in plant density between treated and untreated plots in field No. 1 were more obvious. The visible reduction in plant cover on the untreated check plots was confined to localized areas (Figure 1) which varied considerably in size. Counts of living plants per foot of drill row on two of the untreated check plots in field No. 1 were made at random both within and outside of these obviously damaged spots. These counts along with random counts in adjoining treated plots are presented in table 1.

Table 1.—Comparison of number of living plants per foot of drill row between treated and untreated plots in field No. 1.

| Sample No. | Number of Living Plants per Foot | | | |
|---|---|---|---|---|
| | *Mergamma* 2 oz./bu. | Untreated Check | *Mergamma* 2.25 oz./bu. | Untreated Check |
| 1 | 15 | 3 | 9 | 7 |
| 2 | 14 | 4 | 15 | 12 |
| 3 | 18 | 7 | 13 | 5 |
| 4 | 11 | 11 | 12 | 3 |
| 5 | 10 | 4 | 10 | 8 |
| 6 | 10 | 5 | 11 | 2 |
| 7 | 15 | 8 | 12 | 12 |
| 8 | 9 | 10 | 13 | 7 |
| 9 | 13 | 11 | 13 | 4 |
| 10 | 13 | 4 | 9 | 8 |
| Av. | 12.7 | 6.7 | 11.7 | 6.8 |

Table 2.—Summary of yields obtained from experimental fields.

| Seed Treatment (Ozs. *Mergamma*/bu.) | Field No. 1 | | Field No. 2 | |
|---|---|---|---|---|
| | Acreage | Yield (bu./acre) | Acreage | Yield (bu./acre) |
| 1.75 | 6.4 | 24.6 | 6.0 | 24.1 |
| 2.00 | 6.3 | 18.7 | 6.0 | 23.0 |
| 2.25 | 20.5 | 21.5 | 24.0 | 30.4 |
| 2.50 | 6.4 | 22.5 | 6.0 | |
| | | Av. 21.7 | | Av. 28.1 |
| Untreated check | 12.0 | 18.3 | 24.0 | 21.8 |

It will be noted that the average number of plants per foot of drill row in adjoining treated plots is nearly twice that of the number in the untreated check plots. The extreme variations in numbers of plants found in the samples taken from the untreated check areas is a good indication of the nonuniformity of damage resulting from wireworm attacks. No visible differences in vegetative cover ever became apparent between treated and untreated plots in field No. 2.

The data presented in table 2 indicate that every plot in which treated seed was planted produced more grain per acre than the untreated adjoining check plots. While there was no visible difference in plant cover between the treated and untreated acreage in field No. 2, the yield data shows a marked increase due to treatment for wireworm. Yield increases due to wireworm control varied from 0.4 bushel to as much as 8.6 bushels per acre. On the basis of the yield data and sampling for dead wireworms it is believed that the 2.25 ounces per bushel *Mergamma* treatment gives the greatest amount of protection for the cost involved.

# Spraying for Control of Bean Insects[1]

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During the summer of 1952 four small plot experiments were conducted on the effectiveness of CS-708 and malathion for control of insects attacking snap and lima beans (Ditman 1953). Results of this work indicated: (1) yield increases resulted from malathion and CS-708 treatments when little or no Mexican bean beetle was present; though both insecticides performed excellently on beans, yields from CS-708-emulsion-sprayed plots tended to be slightly higher than those from malathion-emulsion-sprayed plots when the commercial preparations were used at the same dosage per acre; (2) a slightly better protection of plants from Mexican bean beetle resulted from the use of CS-708 sprays when CS-708 and malathion emulsions were applied at the same dosage per acre; (3) plots sprayed with malathion, 50 per cent emulsifiable, at 1½ pints per acre in 20, 30, and 40 gallons of water per acre out-yielded plots sprayed with the same dosage of malathion in 55 and 80 gallons per acre; (4) neither malathion nor CS-708 emulsion sprays gave satisfactory corn earworm control on lima beans. In these experiments the potato leafhopper was the most prevalent pest and yield increases are attributed in part to its control. All sprays in these experiments were applied with a Slosser-type row-crop boom equipped with three nozzles per row (Slosser 1944).

On the basis of results of the 1952 experiments CS-708 emulsion sprays were recommended for use on snap beans while malathion emulsion sprays were recommended on lima beans, the reason being that on the short season snap bean crop, Mexican bean beetle and potato leafhopper are the most important pests, while infestations of black bean aphid and red spider mite frequently occur on the longer season lima beans. Alternate treatments with malathion and CS-708 on either snap or lima beans was a favored method of handling the problem. Commercial emulsifiable concentrates of either insecticide were recommended to be used at 2 pints in 25 gallons of water per acre.

Replicate Plot Experiments, 1953.—Malathion 50 per cent and CS-708 25 per cent emulsifiable concentrates were further compared on an early field of Top Crop snap beans. Both materials were applied at the rate of 2 pints of concentrate in 25 gallons of water per acre and treatments were replicated three times. The sprayer was equipped with three nozzles per row. The beans were planted in late May and sprays were applied June 5, 10, 18, and July 2 and 13. The crop was harvested in two pickings on July 10 and 15. A moderate infestation of Mexican bean beetle was present in addition to potato leafhopper, bean leaf beetle, and spotted cucumber beetle. Results are given in table 1. The picked beans were graded for per cent U. S. No. 1 and per cent pod injury by insects.

**Table 1.—Results obtained with malathion and CS-708 emulsion sprays on early snap beans. 1953.**

| Treatment | Pounds of Beans per Plot | Per Cent of Plants Injured by Bean Beetle | Pods (Per Cent) | |
|---|---|---|---|---|
| | | | U.S. No. 1 | Injured by Insects |
| Malathion | 34.8 | 9.2 | 89.6 | 1.6 |
| CS 708 | 33.5 | 1.5 | 89.6 | 2.0 |
| Check | 19.9 | 54.0 | 87.0 | 4.0 |

A second experiment with malathion and CS-708 emulsion sprays was made on Mid-Summer snap beans. Though this was a multiple-split plot designed experiment involving varieties, plant spacing, fertilization and time of harvest, only the effect of insecticidal treatments on yield is given at this time (Table 2). All treatments were applied at weekly intervals, a total of five applications being made. There was no Mexican bean beetle present and only a light infestation of potato leafhopper. The weather was dry and hot and though plants developed vigorously, the set of fruit was greatly reduced.

[1] Scientific article No. A 445; contribution No. 2506 of the Maryland Agricultural Experiment Station, Department of Entomology.

**Table 2.—Yields of Mid-Summer snap beans sprayed with CS-708 and malathion emulsion.**

| TREATMENT | AMOUNTS PER ACRE IN 25 GAL. WATER (PINTS) | AVERAGE YIELD OF BEANS PER PLOT (POUNDS) |
|---|---|---|
| Check | | 166.6 |
| Malathion 50% | 1½ | 177.2 |
| Malathion 50% | 2 | 186.6 |
| CS-708 25% | 1½ | 192.1 |
| CS-708 25% | 2 | 191.5 |

A third comparison of the performance of malathion and CS-708 emulsion sprays was made on Fordhook lima beans. Eight applications at weekly intervals were made at the 2 pint to 25 gallon per acre rate to randomized blocks which were replicated three times. Differences in yields (Table 3) were caused by a heavy infestation of two-spotted spider mite. Only malathion plots retained their foliage until harvest. The Mexican bean beetle injury was negligible.

**Table 3.—Plant stand and yields of Fordhook lima beans on plots sprayed with malathion and CS-708.**

| TREATMENT | AVERAGE PLANTS PER PLOT | AVERAGE LBS. SHELLED BEANS PER PLOT |
|---|---|---|
| Malathion | 1,091 | 86.9 |
| CS-708 | 1,356 | 65.0 |
| Check | 1,082 | 55.0 |

CORN EARWORM ON LATE LIMA BEANS.—A final experiment was carried out primarily to determine the effectiveness of varying dosages and number of applications of 25 per cent DDT emulsion sprays for control of the corn earworm. All plots received two CS-708 sprays at 2 pints of 25 per cent emulsion in 25 gallons of water on August 4 and 27 and two malathion sprays at 2 pints of 50 per cent emulsion in 25 gallons of water per acre on August 11 and September 10. These treatments were made to control Mexican bean beetle, potato leafhopper, the black bean aphid, and the two-spotted spider mite, which were present during the season on adjacent crops. Corn earworm treatments were started on August 20; the beans were harvested between September 15 and 23. The results of the treatments applied are given in table 4. All sprays were applied in 25 gallons of water per acre and all insecticides were used in the emulsion form. Three nozzles were used per row. The commercial DDT emulsion concentrate was 25 per cent and appeared to be made up with a petroleum solvent.

Examination of the plots before harvest revealed no Mexican bean beetle, leafhopper or spider mite injury. There was no apparent foliage injury from DDT treatments in the field and no reduction in yields where heavy applications of DDT emulsions were made.

COMMERCIAL TREATMENTS.—Four-row Slosser-type booms were constructed by two canners and adapted to two types of tractors (Figures 1 and 2). The first equipment constructed (Figure 1) was used on snap beans for control of Mexican bean beetle, potato leafhopper, and thrips. Three nozzles were used per row; all sprays were applied in 25 gallons of water per acre at a field speed of approximately 5 m. p. h. The snap beans received two treatments about 2 weeks apart, the second treatment being applied at the time the first pods began to form. CS-708 emulsion at 2 pints per acre was used in the first application and either CS-708 or malathion at 2 pints per acre was used in the second application. Excellent insect control was obtained in all fields treated. It does not require as many applications of insecticide in large commercial plantings as in small plot tests where untreated checks are left. On unirrigated commerial acreage severe loss of crop resulted from drought. On an irrigated field of Top Crop variety, four pickings of beans were obtained without reduction of quality of the late pickings.

The second outfit (Figure 2) was used primarily for earworm control on late Henderson-type lima beans. Five nozzles were used per row, one directed down from above, two set wide from the sides of the row, and two set low and close to the row. The low, close pair of nozzles was set at a slight upward angle so as to direct the spray up and inside the bean plant. Hollow-cone nozzles were used in all treatments. For earworm control 2 or 3 pints of 30 per cent DDT emulsion were applied in 25 gallons of water per acre at a field speed of 5 m.p.h., the heavier dosage on late season beans. Definite conclusions could not be drawn regarding the effectiveness of these commercial treatments since no check plots were left. The canner reported that there was no loss of

FIG. 1.—"Slosser" type row crop boom mounted in cultivator position used for spraying snap beans.

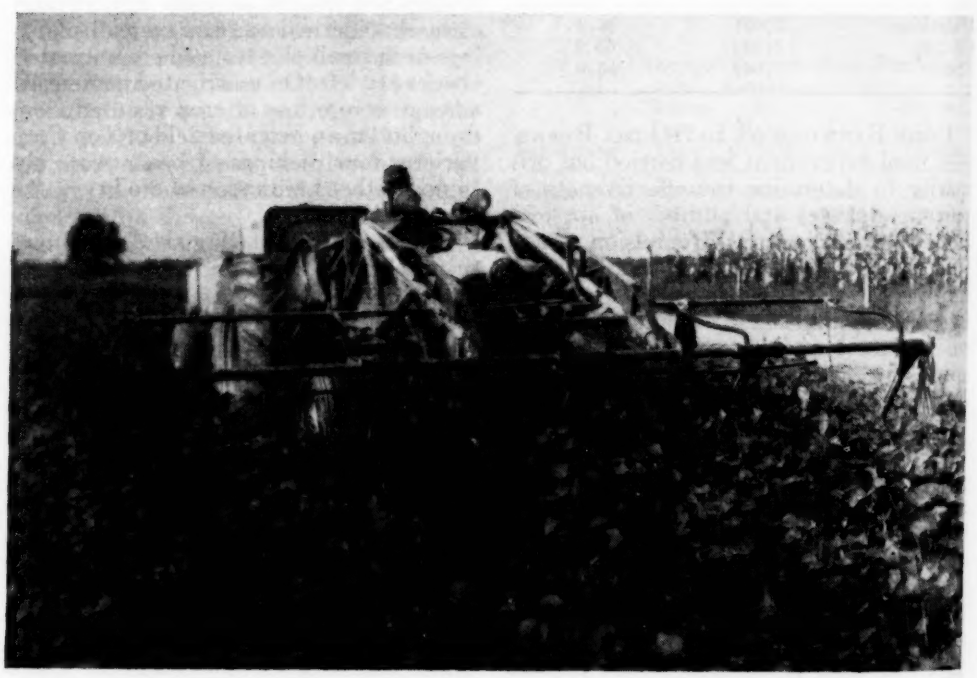

FIG. 2.—"Slosser" type boom mounted on hydraulic lift in front of tractor. A less desirable mounting as spray vapors may be blown over operator on windy days.

**Table 4.—Results of treatments against the corn earworm on Clark Bush lima beans.**

| Insecticide | Rate per Acre (Pints) | Applications | | Per Cent | | Average Yield per Plot (Pounds) |
|---|---|---|---|---|---|---|
| | | Number | Days between | Pods Injured | Control | |
| DDT | 1 | 4 | 7 | 1.6 | 42.8 | 10.3 |
| | 2 | 4 | 7 | 1.2 | 57.1 | 9.8 |
| | 3 | 4 | 7 | 1.6 | 42.8 | 12.1 |
| | 4 | 4 | 7 | 0.6 | 78.5 | 13.7 |
| Control | | | | 2.8 | | 13.2 |
| DDT | 2 | 3 | 10 | 1.4 | 50.0 | 13.5 |
| DDT | 2 | 2 | 14 | 4.4 | | 12.6 |
| CS-708[1] | 1 | 1 | 14 | 3.6 | | 12.8 |

[1] In addition to Mexican bean beetle treatments.

pack because of the presence of worm-eaten beans. On late untreated acreages of lima beans in the vicinity, the quality of the pack was impaired by earworm injury.

Both canners were highly satisfied with the Slosser-type boom equipment. The advantages of this boom are that nozzles are carried at a low constant level from the ground without danger of boom breakage and that excellent spray coverage is obtained.

SUMMARY.—The Slosser-type boom equipment was highly satisfactory for spraying snap and lima beans.

At the same dosages of the commercial emulsifiable concentrates per acre, CS-708 was slightly superior to malathion against the Mexican bean beetle and the potato leafhopper. CS-708 was not effective against black bean aphid and two-spotted spider mite, but malathion was effective against both.

Alternating sprays of CS-708 and malathion appear to be desirable for control of all pests except the corn earworm, particularly on lima beans.

In small-plot tests desired control of the corn earworm was not obtained with three nozzles per row. In commercial treatments using five nozzles per row, corn, earworm control appeared to be satisfactory.

## LITERATURE CITED

Ditman, L. P. 1953. Spraying and dusting for more beans. Rept. Md. Veg. Growers Assn. **34th** Ann. Meeting. Pp. 4–7.

Slosser, John W. 1945. An improved sprayer boom for potatoes and other row crops. Agr. Eng. **26**(11): 453–5.

# Control of Plague Vectors on the California Ground Squirrel by Burrow Dusting with Insecticides and the Seasonal Incidence of Fleas Present[1]

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Meyer & Holdenreid (1949) have discussed well the relationship existing between sylvatic plague in ground squirrels, *Citellus beecheyi* (Richardson), and plague in "domestic" rats. Improved insecticide methods for the control of fleas are warranted because of the economic importance of Siphonaptera as disease vectors and pests on man and domestic animals.

During 1951 eight chlorinated hydrocarbons were tested for the control of fleas on ground squirrels under field conditions; the data indicated that three compounds (aldrin, dieldrin, and heptachlor) should be given additional study. DDT was used as a standard insecticide for comparison.

The second phase of this study was initiated in May, 1952, and was concluded in September, 1953; during this period the flea index in experimental and control fields was followed until the index in the fields treated with aldrin, dieldrin, heptachlor, and DDT approached the control index or was significantly above the economic threshold. A preliminary report of this investigation was made by Ryckman, *et al.* (1953a); those interested in the field techniques developed at the beginning of this project are referred to that report. All data were obtained from ground squirrels retained within electrically fenced enclosures; design and construction of the electrical fences for ectoparasite studies has been reported by Ryckman *et al.* (1953b).

APPLICATION OF INSECTICIDES.—On October 12 to 16, 1952, which was at the height of the flea breeding season, 2.5 per cent heptachlor, 5 per cent DDT, 2 per cent dieldrin, and 2.5 per cent aldrin were dusted into all ground squirrel burrows in test fields, numbers XXI, XXII, XXIII, and XXV respectively. Field number XXIV was used as a seasonal control. A cyanogas dust gun was used to inject the insecticides into burrows at the rate of 30 grams per burrow entrance. Each gun was calibrated as to the amount of dust discharged per stroke. A four-man team systematically applied the insecticides to all burrows.

COLLECTION OF FIELD DATA.—From 7 to 10 days before the insecticides were applied, pretreatment control squirrels were trapped from each of the five electrically fenced fields. These animals were transported to the laboratory and anesthetized with sodium nembutal. Most of the parasites were removed by the suction technique described by Ryckman *et al.* (1954). Anesthetized squirrels were marked and later, when revived, were returned to the field from which they were trapped. Marked squirrels were not recaptured until 30 to 60 days later. The authors have shown that deparasitized squirrels will rapidly become reparasitized when liberated in infested burrows; deparasitized squirrels were retrapped after 10 days and found to have a flea index approximating the index obtained 10 days previously.

DISCUSSION.—The data obtained from October, 1952, through September, 1953, are presented in figure 1. It is the opinion of the authors that all of the data compiled into one visual picture, in the form of a bar graph, presents the reader with a quantitative concept of the results not otherwise possible. A study of the data presented in the graph indicates that the pretreatment flea index ranged from 111 fleas to 318; the seasonal control index at this time was 171 fleas per animal. On the third and fourth day after burrow dusting, the flea index on squirrels exposed to aldrin, dieldrin, and heptachlor dropped from 128, 318, and 111, respectively, to less than one flea per squirrel. During this same period of time the flea index on squirrels exposed to DDT dropped from 258 to 107 fleas per animal. These data give conclusive evidence as to the knock-

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down potential of aldrin, dieldrin, and heptachlor. On the 33rd to 41st day after treatment, the flea indices in the areas dusted with aldrin, dieldrin, and heptachlor were still less than one flea per animal. The DDT index at this time was 6.9 and the seasonal control had declined from 171 to 99.6. In February the cumulative flea index in the seasonal control dropped to 1.2; no data were taken from the experimental fields during the winter months because of the low index in the control field.

It should be emphasized that the seasonal incidence of fleas on the California ground squirrel fluctuates greatly being high in late summer and low in the winter season. In February, 1953, the cumulative flea index was 1.2 and in July of the same year the index was 304.8. Three species of fleas are present on ground squirrels in western San Bernardino County; they are: *Diamanus montanus* (Baker 1895), *Hoplopsyllus anomalus* (Baker 1904), and *Echidnophaga gallinacea* (Westwood 1875). *E. gallinacea* is the numerically dominant flea in southern California during the months of June through October. The seasonal incidence of each flea species in the untreated control unit, the mean temperature, and the rainfall in inches per month are graphically presented in figures 2, 3, and 4.

Linsdale (1946), Stewart & Evans (1941), Holdenreid *et al.* (1951), and Ryckman *et al.* (1954)[3] have reported on the seasonal incidence of fleas on the California ground squirrel.

Following the lowest annual index in February the cumulative seasonal control index rose to 60.8 in May; in July the con-

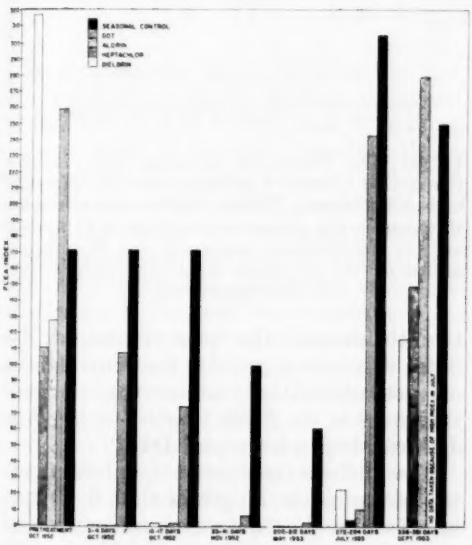


FIG. 1.—Graph indicating the results obtained during a period of 12 months using four insecticides formulated as a dust and injected into all ground squirrel burrows present in four electrically fenced study areas. Each of the four insecticides (DDT 5%, aldrin 2.5%, heptachlor 2.5%, and dieldrin 2%) were applied at a standard dosage of 30 grams per burrow entrance; only the one initial application was made during the period covered by this study.

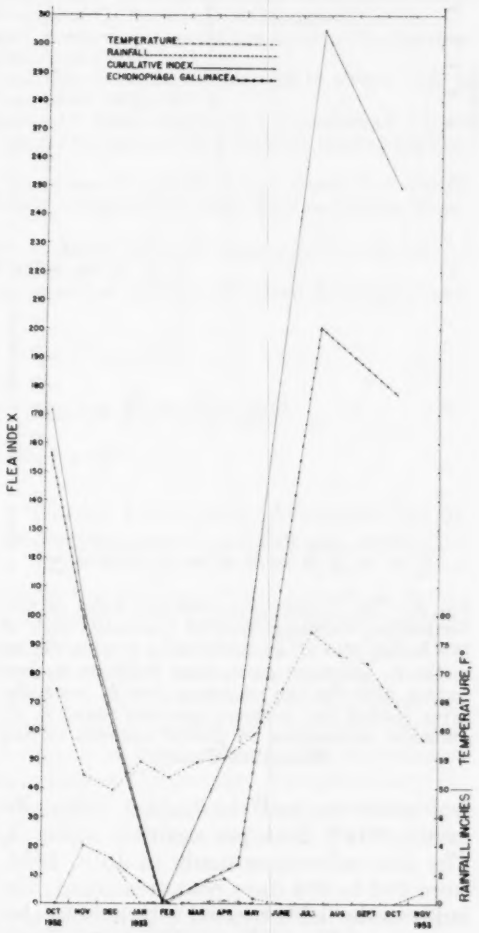


FIG. 2.—*Echidnophaga gallinacea* is the numerically dominant flea on ground squirrels in San Bernardino County, California, during the dry, hot portion of the year, June to November. A continuous rise in the mean temperature during April, May and June and a very low precipitation rate in May and June resulted in an abrupt rise in the *E. gallinacea* index during June.

[3] Manuscript submitted for publication in the JOUR. ECON. ENT. by Raymond E. Ryckman, Chester C. Lindt, Charles T. Ames, and Robert D. Lee entitled, Seasonal Incidence of Fleas on the California Ground Squirrel in Orange County, California.

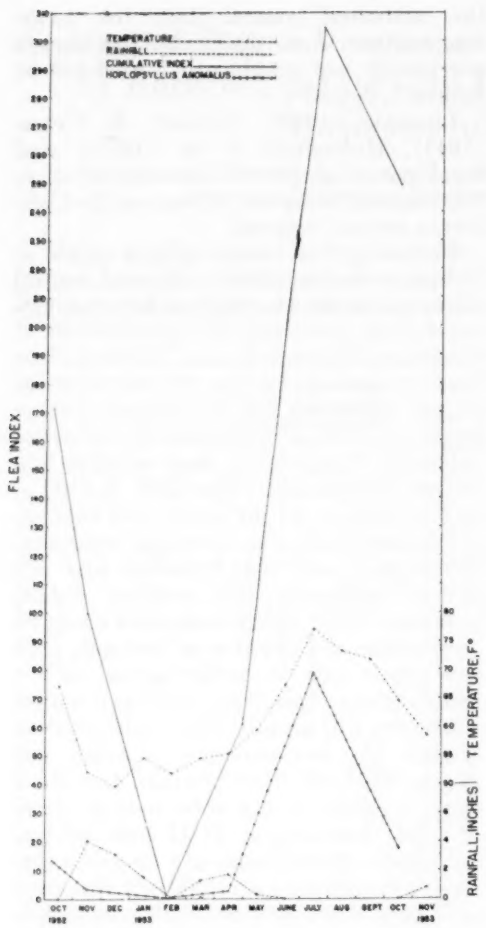


FIG. 3.—The *Hoplopsyllus anomalus* index in San Bernardino, California reached a seasonal high of 78.8 in July; the *H. anomalus* curve is quite similar to the *E. gallinacea* curve from February to November with the one exception that *H. anomalus* never reaches the populous numbers found in *E. gallinacea* infestations on ground squirrels in San Bernardino County.

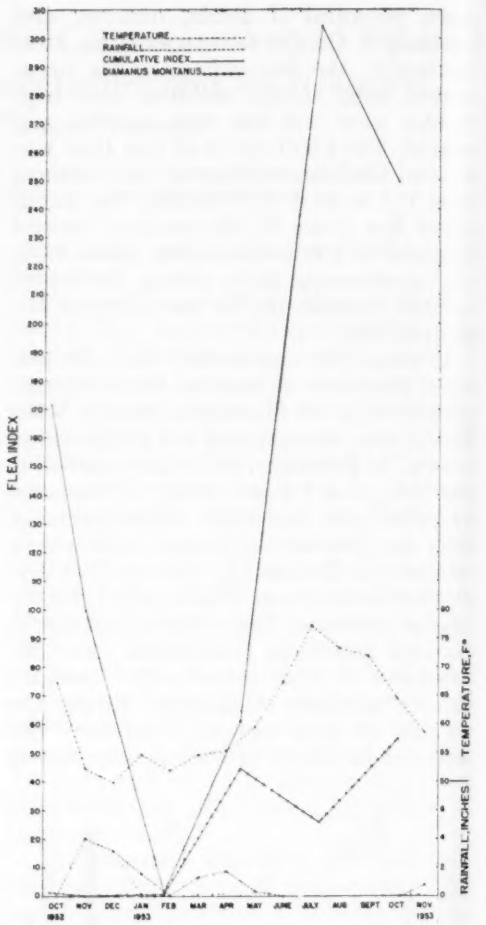


FIG. 4.—The *Diamanus montanus* index in San Bernardino County, California reached an annual high of 54.8 during October; this species was not as abundant on the ground squirrel host at its seasonal high as *Echidnophaga gallinacea* and *Hoplopsyllus anomalus* with an annual maximum index of 200.2 and 78.8 respectively.

trol index reached the highest index obtained, 304.8 fleas per squirrel, figure 1. The flea collections made in July, 1953, were 272 to 284 days post-treatment; the index in the fields treated with insecticides were as follows: heptachlor 4.3, aldrin 11.1, dieldrin 23.2, and DDT 242.5. From these data it is apparent that DDT did not control *Echidnophaga gallinacea*, *Diamanus montanus*, and *Hoplopsyllus anomalus* 9 months after application as a 5 per cent dust in the burrows. The flea index began a small but significant rise in the aldrin, dieldrin, and heptachlor treated fields 9 months post-treatment. By the twelfth month the post-treatment flea index was approximating the control index or was substantially above the economic threshold in the fields treated with aldrin, dieldrin, heptachlor, and DDT.

The authors conducted the above study to determine the length of time flea populations may be controlled under natural conditions when aldrin, dieldrin, heptachlor, and DDT were applied in dust form to ground squirrel burrows. The reader's attention is directed to several other important considerations in evaluation of the data herein presented. A relatively small amount of each insecticide was used per acre because only the burrows were

treated and not the entire surface of the test field. The burrows in each field treated were dusted when the colonies were well established; however, burrows made after the initial treatment were of course not dusted. Squirrels frequently enlarge their burrows at which time untreated soil would be mixed with treated soil in the burrow system. The investigators believe that these data indicate that aldrin, dieldrin, or heptachlor dusted into burrows over a large area may be expected to keep the flea population below the level of economic importance up to 9 months. A study is nearing completion concerned with the comparative duration of control when an insecticide is applied as a spray to burrows, as a spray to the entire surface of the test field, and as a dust to the surface of the soil and vegetation.

## LITERATURE CITED

**Holdenreid, R. F.,** F. C. Evans, and D. S. Longanecker. 1951. Host-parasite-disease relationships in a mammalian community in the central coast range of California. Ecol. Mongr. **21**: 1–18.

**Linsdale, Jean M.** 1946. The California ground squirrel, a record of observations made on the Hastings Natural History Reservation. University of California Press. Berkeley.

**Meyer, Karl F.,** and R. Holdenreid. 1949. Rodents and fleas in a plague epizootic in a rural area in California. Puerto Rico Jour. Pub. Health Trop. Med. **24**(3): 201–9.

**Ryckman, Raymond E.,** Charles T. Ames, and Chester C. Lindt. 1953a. A comparison of Aldrin, Dieldrin, Heptachlor and DDT for control of plague vectors on the California ground squirrel. JOUR. ECON. ENT. **46**(4): 598–601.

**Ryckman, Raymond E.,** Karl C. Fischer, Charles T. Ames, and Chester C. Lindt. 1953b. The electric fence as an aid in field studies of rodents and their ectoparasites. Calif. Fish and Game. **39**(4): 489–96.

**Ryckman, Raymond E.,** Karl C. Fischer, and Charles T. Ames. 1954. An apparatus for collection of ectoparasites from mammals. Calif. Fish and Game. **40**(1): 75–6.

**Stewart, M. A.,** and F. C. Evans. 1941. A comparative study of rodent and burrow flea populations. Proc. Soc. Exper. Biol. and Med. **47**: 140–2.

# Control of Root Maggots in Rutabagas[1]

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Root maggots are undoubtedly the chief production factor limiting the commercial growing of table grade rutabagas in many parts of British Columbia. Practical control has been lacking although Glendenning (1944, 1950[4]) found that, although infestation in rutabagas was substantially reduced by five to seven applications of corrosive sublimate spray or calomel dust, the cost was excessive.

The present paper summarizes the results from the authors' work with root maggots in rutabagas on Vancouver Island from 1948 to 1952, in three main phases: (a) reconnaissance studies in 1948 and 1949; (b) extensive developmental tests in 1950 and 1951; and (c) two large-scale experiments in replicated blocks in 1952.[5] Methods of evaluating the results are appraised. Use is made of some pertinent facts gained from 1946 to date in studies of the biology of root maggots (Forbes, unpublished) and extensive chemical control experiments annually with the same species in cabbage and cauliflower (King & Forbes, unpublished).

SPECIES INVOLVED.—As established by the reconnaissance studies and confirmed in later findings, the chief species of root maggot attacking rutabagas on Vancouver Island is the cabbage maggot, *Hylemya brassicae* (Bouché) (Diptera: Anthomyiidae). The turnip maggot, *H. floralis* (Fall.) (=*H. crucifera* Huck.), also occurred in considerable numbers during August and September in the experimental plots at Courtenay. The secondary *H. cilicrura* (Rond.)—*H. trichodactyla* (Rond.) complex occurred in variable

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[3] The authors gratefully acknowledge:—assistance throughout the experiments by M. D. Noble, Technician, and on occasion by A. T. Wilkinson, Agricultural Research Officer; the exchange of ideas with R. Glendenning, Officer-in-Charge of the Canada Entomology Laboratory, Agassiz, B.C., and L. L. Stitt, Entomologist at Western Washington Experiment Station, Puyallup; and the help of A. R. Brooks (cf. 1951) for the initial identifications of immature material of the pest group.

[4] Glendenning, R., 1950. Root maggots on turnips; a summary of progress in control. Unpublished manuscript.

[5] Similar experiments conducted in 1953 under a coordinated plan with two other laboratories in British Columbia and one in Western Washington, are to be reported in a joint publication.

numbers on rutabagas on Vancouver Island generally.

RECONNAISSANCE STUDIES, 1948–49.—At the time these studies with rutabagas were incepted, chemical control of the same pest on stem crucifers, such as cabbage and cauliflower, had long been established on a practical basis. Experiments were proving that some of the chlorinated hydrocarbons, applied by any of several different simple means, were giving, at lower cost, substantially more effective control. It was natural to hope that these newer insecticides would achieve similar, or at least substantially improved, results with the root crucifers, radish, turnip and rutabagas. In fact many insecticide dealers in the Province, and even some agriculturists, concluded that this result would necessarily follow, and were already recommending for rutabagas, without testing, one of the treatments that the authors had proved (see King 1949, "Officials" 1949) to be effective with cabbage, namely, dusting the young plants with chlordane. The similar use of DDT dust was also suggested by some. A number of growers tried this treatment, usually with disappointing results. A few reported worthwhile benefit from dusting with chlordane, but in no such instance did investigation find any direct comparison with untreated rutabagas. In most instances, the crop so treated was very heavily infested with maggots at harvest time.

The ineffectiveness of such treatments was further demonstrated in preliminary experiments at Comox in 1949. Two "heavy" dustings along the rows with 5 per cent chlordane were made by the grower, the first being applied when the rutabagas were in the two-leaf stage, the second just after a late thinning. Sampling in October showed that, although maggot attack in the early stages was reduced by the treatment, the ultimate damage was exceptionally heavy and as great in the treated part of the field as it was in the untreated check rows. In a similar experiment with DDT dust the infestation counts in the treated rows were heavier than where no treatment was given, though the insecticide had been applied at exceedingly heavy rates.

Investigation to determine the causes underlying this wide disparity of the effectiveness of a chemical on stem crucifers and on rutabagas showed that fundamental differences exist between the two crops, in duration of the critical period of infestation and in size and nature of the critical zone for possible attack. Experiments with cabbage transplants showed that a treatment affords adequate practical control if it prevents deep penetration of the main root during the short period before secondary roots become well established. For example in 1949, the plots receiving "DDT dip" treatment showed an average infestation when the heads were mature of 4.6 puparia per plant, as compared with 3.2 in the check plots, without adverse effect on either stand or yield. In contrast, it was found that with rutabagas a "control" of that kind is valueless. Infestation is of practical significance in rutabagas at any time throughout the long period from emergence of the seedlings in June until the crop is harvested in late autumn; even a single larva may render a root unacceptable for table grade (see below). Moreover, the critical area was found to include the whole of the fleshy root, as considerable infestation can take place even well above the soil level in some seasons. This is a zone of large size (relative to cabbage) which expands enormously during the season of growth. There is also evidence (particularly from Stitt, personal communication) that rutabagas are more subject to infestation and damage by the root maggot than are summer turnips.

Based on these reconnaissance studies, four methods of insecticide application were selected as affording promise of adaptability to field scale use with rutabagas, and appraisal methods applicable to this problem were developed. These, described below, have remained basically unchanged during the course of the subsequent field experiments, though some refinements have been made. Together with those on cabbage and cauliflower, these studies also guided the selection of chemicals and range of rates for initial testing, and eliminated DDT from further consideration.

MATERIALS AND APPLICATION METHODS.—The Laurentian variety of rutabagas (swede turnips) was used throughout. Seeding was done with a Planet Junior drill except as noted. The crops at Victoria and Thetis Lake received overhead sprinkling twice during the early period of growth each season. All other crops had only natural moisture, even though all

three growing seasons, 1950–52 especially the latter, were very dry until late in the autumn.

The insecticides used were standard formulations of the period.[6]

Throughout these experiments, hand methods of application were used to give greater precision in both the quantity and placement of the insecticide. Four main methods were employed, as follows:—The *band method* and *furrow method* each involved a single application of an insecticide dust in the soil at time of planting. The *spray method* and *dust method* each involved two applications to the crowns of the plants and adjacent soil surface, the first application being made soon after the seedlings were well up and the second application when the crop growth was well advanced but would still have permitted the practical use of power spraying or dusting equipment.[7] In the band method, the insecticide was spread evenly on the soil in a 10 to 12 inch band, raked in not more than 1 inch deep, and the seed immediately planted along the center of the band. In the furrow method

**Table 1.—Root maggot control at Courtenay, 1950.**

| Chemical | Active Ingredient per Acre | Plots | Unmarketable[1] | Infestation | Control |
|---|---|---|---|---|---|
| | *Pounds* | *Number* | *Per cent* | *Index* | *Per cent* |
| Untreated | Nil | 11 | 68 | 81 | — |
| | | *Band Method* | | | |
| Aldrin | 10 | 1 | 0 | 9 | 89 |
| | 5 | 1 | 0 | 11 | 86 |
| | 2 | 2 | 22 | 44 | 45 |
| BHC (gamma isomer) | 0.5 | 1 | 40 | 60 | 26 |
| Chlordane | 22 | 1 | 0 | 13 | 84 |
| | 10 | 1 | 8 | 27 | 67 |
| | 7 | 1 | 20 | 47 | 42 |
| | 3 | 2 | 48 | 67 | 17 |
| Dieldrin | 5 | 1 | 16 | 39 | 51 |
| Heptachlor | 7 | 1 | 0 | 10 | 88 |
| | 3.5 | 1 | 4 | 19 | 77 |
| | 1.5 | 1 | 36 | 51 | 37 |
| | | *Dust Method* | | | |
| Aldrin | 2 | 2 | 23 | 48 | 41 |
| | 1 | 3 | 45 | 67 | 17 |
| BHC(gamma isomer) | 1 | 1 | 6 | 19 | 77 |
| | 0.5 | 1 | 36 | 58 | 28 |
| Chlordane | 10 | 3 | 24 | 46 | 43 |
| | 7 | 2 | 26 | 50 | 38 |
| | 5 | 4 | 57 | 75 | 7 |
| Dieldrin | 2 | 1 | 2 | 18 | 78 |
| | 1 | 1 | 8 | 24 | 71 |
| Heptachlor | 2 | 1 | 56 | 70 | 14 |
| | | *Furrow Method* | | | |
| Aldrin | 2.5 | 1 | 0 | 11 | 86 |
| | 1 | 1 | 4 | 22 | 73 |
| BHC (gamma isomer) | 0.25 | 1 | 32 | 45 | 44 |
| Chlordane | 5 | 1 | 36 | 52 | 36 |
| Heptachlor[2] | 2 | 1 | 47 | 62 | 23 |
| | | *Spray Method* | | | |
| Aldrin | 4 | 2 | 6 | 23 | 72 |
| | 2 | 2 | 30 | 52 | 36 |
| BHC (gamma isomer) | 1 | 1 | 8 | 25 | 70 |
| | 0.5 | 1 | 48 | 73 | 10 |
| Chlordane | 8 | 2 | 6 | 29 | 64 |
| | 4 | 2 | 22 | 53 | 35 |
| Dieldrin | 4 | 2 | 9 | 22 | 73 |
| | 2 | 2 | 14 | 35 | 57 |
| Heptachlor | 4 | 1 | 8 | 34 | 58 |
| | 2 | 1 | 16 | 46 | 43 |
| Parathion | 1 | 1 | 12 | 47 | 42 |
| | 0.5 | 1 | 40 | 70 | 14 |

[1] Unmarketable = those of the "severe" category.
[2] Poor growing conditions in plot, results not representative.

**Table 2.—Root maggot control at Victoria, 1952.**

| Chemical | Active Ingredient per Acre | Unmarketable | Damage | Control |
|---|---|---|---|---|
| | *Pounds* | *Per cent* | *Index* | *Per cent* |
| Untreated | Nil | 85 | 90 | — |
| Water | Nil | 89 | 93 | — |
| | | *Band Method* | | |
| Aldrin | 5 | 7 | 16 | 82 |
| | 2.5 | 21 | 30 | 67 |
| Chlordane | 10 | 41 | 54 | 40 |
| Heptachlor | 5 | 4 | 13 | 86 |
| | 2.5 | 17 | 29 | 68 |
| | | *Band plus dust Method* | | |
| Aldrin | 5 | 6 | 14 | 84 |
| | | *Dust Method* | | |
| Aldrin | 4 | 11 | 21 | 77 |
| Dieldrin | 2 | 17 | 29 | 68 |
| Heptachlor | 8 | 12 | 21 | 76 |
| | | *Furrow Method* | | |
| Aldrin | 2.5 | 4 | 14 | 84 |
| Heptachlor | 2.5 | 6 | 12 | 87 |
| | | *Spray Method* | | |
| Aldrin | 5 | 7 | 12 | 87 |
| | 3 | 8 | 19 | 79 |
| Heptachlor | 3 | 6 | 13 | 86 |
| LSD (5 per cent level) | | 12 | 13 | — |

[6] Aldrin and dieldrin were each used as 1 and 2½ per cent dusts a 25 per cent wettable powder, and an emulsifiable concentrate containing 4 lb. (aldrin 1950 only) or 2 lb. of toxicant per gallon; all were contributed by Julius Hyman & Co., Denver, Colo.

Chlordane was used as a 10 per cent dust, a 40 per cent wettable powder, and an emulsifiable concentrate containing 8 lb. per U.S. gal., all contributed by Velsicol Corporation, Chicago, Ill.; and as a 5 per cent dust formulated by Commercial Chemicals Ltd., Vancouver, B. C.

Heptachlor was used as 2½ and 10 per cent dusts, and emulsifiable concentrates containing 4 lb. (1950 only) or 2 lb. per U.S. gal.; also contributed by Velsicol Corp.

Parathion (1950 only) was used as a 25 per cent wettable powder contributed by American Cyanamid Co., New York 20, New York.

BHC (1950 and 1951) was used as a 5 per cent (0.5 per cent gamma) dust formulated by Canadian Industries, Ltd., New Westminster, B. C.; and as a 50 per cent (6 per cent gamma) wettable powder formulated by Dow Chemical Co., Midland, Mich. Lindane (1951 only) was used as a 75 per cent wettable powder formulated by California Spray Chemicals, Richmond, Calif.

[7] The dates of seeding, of the first and second applications by the spray or dust methods, and of harvest sampling, respectively, were as follows for the several experiments:—1950: at Alberni, June 15, July 19, Aug. 1, Oct. 31; at Courtenay, June 21, July 5, Aug. 15, Nov. 1; at Thetis Lake, June 14, July 3, July 13, (with a third application on Aug. 8), Oct. 17. 1951: at Alberni, June 8, June 18, Aug. 2, Oct. 18; at Courtenay, June 19, June 28, Aug. 15, Oct. 15; at Thetis Lake, June 11, June 21, Aug. 6, (third application of spray Aug. 31), Oct. 26. 1952: at Courtenay, June 19, July 15, Aug. 21, Nov. 10; at Thetis Lake, June 12, (no dusts or sprays), Oct. 6; at Victoria, June 17, July 16, Aug. 19, Oct. 28.

the planting furrow was opened with a hoe, the insecticide applied in it, and the row immediately seeded and covered with the drill. In the spray method, the rate of 200 imp. gallons per acre at each application was used throughout the experiments, except in 1950 and 1951 when the 100-gallon rate was also tested. In the 1952 experiments (see Tables 2 and 3): for the "band plus dust" treatment half of the toxicant was applied by each method, the latter at the time of the first regular "dust" application; and the "wet" check plots were sprayed with water at the same times and rates as the spray-treated plots.

For each treatment, the rate per acre stated is the total amount of toxicant applied, being, for the spray and dust methods, the sum of the separate applications.

These rates per acre are based on 14,520 row-feet per acre, i.e. rows 3 feet apart. On this basis, nearly one-third of the surface area is treated with insecticide by the band, spray or dust method, and approximately one-ninth by the furrow method. Thus, a rate of 1 pound of toxicant per acre by the furrow method, gives, *in the area treated*, a concentration of insecticide equivalent to about 3 pounds of toxicant per acre by the band, spray or dust method, and equivalent to a general or broadcast treatment of about 9 pounds per acre.

**Table 3.—Root Maggot Control at Courtenay, 1952.**

| Chemical | Active Ingredient per Acre | Unmarketable | Damage | Control |
|---|---|---|---|---|
| | *Pounds* | *Per cent* | *Index* | *Per cent* |
| Untreated | Nil | 18 | 21 | — |
| Water | Nil | 18 | 21 | — |
| | | *Band Method* | | |
| Aldrin[1] | 5 | 8 | 13 | 38 |
| | 2.5 | 11 | 15 | 29 |
| Chlordane | 10 | 11 | 15 | 29 |
| Heptachlor | 5 | 1 | 3 | 86 |
| | 2.5 | 15 | 18 | 14 |
| | | *Band plus dust Method* | | |
| Aldrin | 5 | 4 | 6 | 71 |
| | | *Dust Method* | | |
| Aldrin | 4 | 5 | 8 | 64 |
| Dieldrin | 2 | 9 | 12 | 43 |
| Heptachlor | 8 | 1 | 1 | 95 |
| | | *Furrow Method* | | |
| Aldrin | 2.5 | 1 | 3 | 86 |
| Heptachlor | 2.5 | 1 | 2 | 90 |
| | | *Spray Method* | | |
| Aldrin | 5 | 1 | 2 | 90 |
| | 3 | 4 | 5 | 76 |
| Heptachlor | 3 | 1 | 3 | 86 |
| LSD (5 per cent level) | | 5.6 | 6.4 | |

[1] Misleading: little maggot attack but it consisted of deep penetrations.

Appraisal Methods.—In all experiments, final appraisal was based on data taken in the field at time of harvest. From each plot was taken a sample consisting either of all the roots of marketable size or of 25 or 50 roots, depending on the size of plot in that experiment. Each rutabaga of the sample was examined and assigned to one of four categories. Roots falling at the border line between any two categories were assigned alternately starting with the higher category.

The four categories, with their definitions and the numerical factors assigned to them, were as follows:—

*Clean*—factor of zero—no evidence on the root of even the slightest feeding definitely attributable to maggot.

*Light*—factor of one—maggot injury limited to superficial early feeding of slight extent and fully healed over, i.e., definite evidence of maggot attack but effect negligible commercially even if all the roots were so affected.

*Moderate*—factor of two—marketable for second grade after special trimming limited to one stroke just above the tap root to remove a single deep penetration or a moderately extensive surface injury; if maggot injury was present at the middle or upper part of the fleshy root it must be fully healed over, no deeper than would be completely removed by normal peeling at time of preparation for cooking, and must not involve more than one-fifth of the surface area.

*Severe*—factor of four—unmarketable for table use; injury not removable by any practical amount of trimming. Except as defined for moderate, a single deep penetration, or the presence of a maggot in the root at harvesting, or any extensive unhealed surface injury, grades a root "severe."

The numerical factors, selected as being approximately proportional to the economic severity of the attack, were employed to permit the data for each plot to be combined into a single figure, either as an "infestation index" or as a "damage index," each ranging from zero to 100.

The *infestation index* (as used in Table 1) is calculated for each plot by multiply-

ing the appropriate factor by the percentage of roots in each category, adding the products, and dividing this sum by four. Thus if the roots from a plot were all graded "severe," the index would be 100; if all were "moderate," 50; if all were "light," 25; and if all were "clean," zero. The infestation index gives greater emphasis to the total impact of the pest upon the roots.

The *damage index* (as used in Tables 2 and 3) was calculated in the same way except that the factor of zero was applied to both the "light" and the "clean" categories, thus taking into account the fact that "light" attack is actually negligible damage. The damage index places the emphasis on the degree of commercial control achieved by the treatments, and minimizes the evidence of larvae that reach the roots but die before they have caused injury of any practical importance.

The *percentage control* was calculated in the standard way. Adjustment for the extent to which the check index (averaged for all untreated plots) falls below the maximum of 100, was made by dividing the check index into each treatment index multiplied by 100. The percentage thus derived represents the total "infestation" or "damage," as the case may be, expressed on a basis that facilitates comparisons between experiments. Subtracting this percentage from 100 per cent gives the percentage control, which represents the reduction attributable to the treatment.

DEVELOPMENTAL TESTS, 1950–51.—Of the seven experiments, the one at Courtenay in 1950 was the most productive of reliable leads because conditions were nearly ideal. The infestation was exceptionally uniform. For the 11, randomly distributed, check plots, the coefficient of variability of the infestation index was only 8.3. Similar indication of reliability of the data was given by the 13 instances where two or more plots received the same treatment. Finally, as brought out in table 1, there was a striking parallel between rate of toxicant and per cent control in every instance where the same insecticide applied by the same method was used at more than one rate. These facts make it evident that the wider differences in degree of control achieved by the several treatments provide a valid basis on which to form tentative conclusions. This experiment involved 39 treatments and check in 67 single-row plots comprising three-quarters of an acre of rutabagas.

At Alberni in 1950 there were two treatments and check, in duplicate, on a considerable acreage. Two very heavy, but delayed, applications by the "dust method" of 2.5 per cent aldrin or 5 per cent chlordane, had little practical effect on the marketability of the heavily infested crop. The relative effect was much poorer than with comparable treatments, in the other tests, in which the first application was made when the plants were small.

At Thetis Lake (near Victoria) tests were carried out in 1950 and 1951 (also in 1952) each using six to eight treatments in single or duplicate small plots under conditions of heavy infestation. In 1950, 95 to 80 per cent control was give by a heptachlor band treatment at 3 pounds per acre, an aldrin spray treatment with three applications totalling $7\frac{1}{2}$ pounds, an aldrin band treatment at $2\frac{1}{2}$ pounds, and a chlordane band treatment at 10 pounds, in that order. Chlordane spray with three applications totalling $7\frac{1}{2}$ pounds per acre gave 65 per cent control; but chlordane dust at the same rate was ineffective. In the 1951 test, two applications of BHC dust at 0.75 pound gamma-isomer per acre or of lindane spray at 1 pound per acre were ineffective.

In 1951, extensive experiments were duplicated at Alberni and Courtenay. Each involved 71 plots, with 23 treatments in duplicate and 10 check plots, randomized, together with some supplementary tests. Aldrin, BHC, chlordane, dieldrin, heptachlor and parathion were each applied at one or more rates by one or more of the four methods. Chief attention was given to the spray and dust methods. Significance was appraised by analysis of variance, using the infestation index.

At Courtenay, the growing season was exceptionally dry. Infestation and damage were very light and variable. The average infestation index for the check plots was only 24.5 with a coefficient of variability of 39.2. Only 11 per cent of the untreated roots were "unmarketable." Nearly all of the treatments effected a significant reduction of the infestation index and for 12 of them it was highly significant; for both groups all or nearly all of the roots were marketable. Those treatments which failed to effect control of this

very low hazard therefore have greater practical meaning. Dosages, expressed as pounds per acre, were: furrow treatment, BHC 0.5, aldrin 1, heptachlor 2, dieldrin 1; seed treatment with DDT; dust method treatment, chlordane 10, dieldrin 0.75; band treatment, heptachlor 2. The other treatments are listed by methods, chemicals and pounds per acre, using one or two asterisks respectively to indicate significance at the 5 per cent or 1 per cent level, respectively. Band method: aldrin 5 **, 2 *; BHC 1 **; chlordane 8 **; dieldrin 3 **; heptachlor 2 *. Dust method: aldrin 5 **, 3 *; BHC 1 **, 0.75 **; dieldrin 1.5 *, 1 single early application **; heptachlor 4 *. Furrow method: none. Spray method: aldrin 5 **, 3 * (both 100 gal. & 200 gal. rates); BHC 1 *; chlordane 7 *; dieldrin 4 **, 2 **; heptachlor 5 **, 3 **; lindane 1 *; parathion 2 *.

The contrast shown by the 1951 results at Alberni was very great. Infestation was uniformly high, resulting in heavy losses. The infestation index for the untreated checks averaged 84 with coefficient of variability of only 7.6. Seventy per cent of the untreated roots were "unmarketable," and the average for all treatments was 51 per cent. Highly significant reduction of the infestation index was effected by only four treatments, and significant by one other. These were as follows, the most effective listed first: heptachlor spray method at 5 and 3 pounds, aldrin spray at 5 pounds, aldrin dust method at 5 pounds; and dieldrin spray at 4 pounds. Only the two heptachlor sprays, with more than 80 per cent of the roots marketable, gave "satisfactory" commercial control, although the other three treatments gave nearly 70 per cent marketable roots.

For these five treatments in 1951 the average percentage control based on the infestation index was 46 at Alberni as compared with 85 at Courtenay. For four other treatments which have been effective in several other experiments the contrast was even greater, the percentage control averaging 11 at Alberni and 77 at Courtenay. These figures allow direct comparison as the percentages derive from the averages for the respective checks, thus minimizing the influence of the widely contrasting infestation hazard in the two places. The differences in control therefore were too large to be attributed to weather factors, though moisture was somewhat greater at Alberni, especially in the late season. It was concluded that the main critical factors lay in the soil differences, as discussed below.

Although, for brevity, results for only one of these seven experiments are given in detail (Table 1), the other six nevertheless contributed substantial additional support, particularly by the cumulative effect of similar indications, for the broader conclusions now stated.

The results gave strong indication that satisfactory commercial control of root maggots on rutabagas grown in loam soils is possible with several of the chemicals tested. Aldrin, heptachlor and dieldrin were the most promising, considering rate and cost as well as effectiveness. The effectiveness of these chemicals varied when applied by the different methods. Aldrin gave good results by the band, furrow and spray methods but was less effective by the dust method. Dieldrin was effective when applied by the spray or the dust method; it was not adequately tested in the furrow. Heptachlor showed best by the band method, but neither the furrow nor the spray method was adequately tested. BHC was effective only at rates impractical because of the risk of off-flavor. Chlordane (except at a very heavy rate) and parathion were ineffective as tested. All four methods of application were found to warrant further testing, although the dust method showed the least promise. The 200-gallon per acre rate gave better coverage in the second spray application than the 100-gallon rate. Control was markedly less effective when the initial application of insecticide was delayed until the fleshy roots had begun to grow and maggot infestation had already become established.

The developmental tests thus provided the basis of selection not only of chemicals but also of methods of application and rates appropriate for each, information essential to the next stage of more precise field experiments restricted to a small number of treatments.

1952 EXPERIMENTS.—Identical tests at Victoria and Courtenay each comprised 64 plots, four replications of 14 treatments and two checks in randomized blocks, each plot consisting of 50 row-feet of rutabagas. Results are summed up in tables 2 and 3. Significance was tested by analysis of variance.

Adequate control of root maggots on rutabagas was again obtained in 1952 with aldrin and heptachlor. These two materials when applied by the band, furrow and spray methods at adequate rates gave better than 80 per cent reduction in damage, representing more than 95 per cent commercial control under present grading. Applied by the dust method, aldrin, dieldrin and heptachlor gave generally mediocre results except in a single instance at Courtenay, where heptachlor at the heavy rate of 8 pounds of toxicant per acre gave 95 per cent control. Chlordane used in a band treatment at the heavy rate of 10 pounds of toxicant per acre gave unsatisfactory control. The results at Courtenay, where the infestation was very light, were about the same as those obtained under the rather heavy infestation at Victoria, though some points of difference may have significance.

DISCUSSION.—Undesirable flavor or quality attributed to insecticide was not reported[8] except with BHC for which the higher rates of application resulted in strongly objectionable flavor.

Evidence of phytotoxic effect of the treatments was observed only for the furrow method of application. In 1950 at Courtenay, acre-dosages of aldrin at 2.5 (but not at 1 pound), BHC at 0.25 pound gamma isomer and heptachlor at 2 pounds, when used by the furrow method, somewhat affected the early growth generally and possibly the stand. Otherwise, phytotoxicity was of little or no importance in these experiments as it did not involve all furrow treatments and where found was usually restricted to one plot or other small portion of the area of the treatment involved. However, the repeated indications of phytotoxic hazard with the furrow application evidence the need for special study directed to that point.

As a result of recommendations (King *et al.* 1953, Officials 1953) based on these experiments, aldrin applied by the band method has been successfully used on a commercial scale by rutabaga growers. However, there is need to develop equipment for large-scale application and to prove it capable of achieving the effectiveness demonstrated for application by hand.

The investigations showed that, to be effective, adequate amounts of the chemical, either by residual action or by renewal, must be present in the critical zone throughout the long period from soon after the rutabagas emerge in late June until they are harvested late in the autumn. Comparison of rates effective for the band and the furrow methods, observations on egg laying, and other data, all suggest that the very superficial layer of soil next to the roots is the critical zone. Concentration of the chemical in that zone is desirable if control is to be secured most economically.

There was indication that soil characteristics may have an important effect on control of root maggots of rutabagas. In particular, greatly reduced control found in the 1951 test at Alberni seemed to be related primarily to the nature and condition of the surface soil which was extremely loose and friable, and had a high content of organic material part of it incompletely broken down. Other observations have been made which support this view. They suggest that the looseness of this kind of soil may favor the occurrence or survival of infestation, or facilitate the movement of larvae to the most critical zone of the root. Another possible factor is of course the known effect of high organic content upon insecticides. Whatever the factor or factors involved, it is clear that the present conclusions apply only to loam soils similar to those in which most of the experiments were carried out.

Similarly, a reservation should be made in respect of seasonal weather conditions, as treatments have not been adequately tested in a season having a wet autumn, such as that of 1949 when an extremely heavy infestation developed shortly before harvest. They have, however, proved effective under other conditions of heavy infestation, including crops which received sprinkler irrigation.

From the research standpoint, probably the most critical aspect of an investigation of this type is the method of appraisal of root maggot damage and control. Therefore, much study has been given to this, taking into account the biological information that has been accumulated, as well as the viewpoints of the practical growers and commercial graders and the need for a method efficiently applicable to large-scale sampling in the field. This

[8] Throughout the experiments, several families reported independently on numbered lots of roots, the origin of which was unknown to them, consumed in normal home use.

led to the development of the procedure used for the 1950 data and employed without essential change for all of our subsequent work. Communicated in January 1951 to a committee of workers interested in this field at the Pacific Northwest Vegetable Insect Conference at Portland, Oregon, it was adopted and has become more or less the standard procedure in the Pacific Northwest (Footnote to Table 6 Morrison & Crowell 1952, Stitt 1953).

In developing the procedure for appraisal, the use of commercial grading standards was first considered, but was rejected for two main reasons: first, even the present grading was found to vary widely not only from place to place but also from time to time, depending largely on the interaction of supply and demand; second, commercial grading standards become progressively more severe as effective means of controlling a serious pest are developed.

Consideration was likewise given to recording, for each root, every gradation of attack such as the estimated number of larvae involved at each period of the season, the location of attack on the root, the wounds healed over or open or with maggots still present, and whether superficial or penetrating, involving extensive or restricted surface area, and all combinations of these (cf. Oughton 1952). All of these points indeed warrant consideration, chiefly in conjunction with biological studies maintained throughout the season. For the harvest appraisal of damage and control, it seems sufficient to cover these other aspects by brief general notes for each at the time it is examined. The detailed method was rejected for the harvest appraisal as requiring an impractical amount of time without adding information critical to the main purpose of the experiment.

Dividing the present, very widespread "severe" category by adding a new "very severe" category was considered but rejected. Although it provided still more accurate measure of the severity of attack with small addition to the time required for appraisal and recording, it was found to be a further complication that in essence added little or nothing of practical value.

For large-scale experiments, the method of harvest appraisal should be rapid and straightforward, to facilitate the examination of large numbers of roots. It must provide data that are closely comparable between different workers or in different years. Though the categories are necessarily subjective, the method should minimize the personal factor by making the definitions clear and precise, specifically providing for the various types of injury that may be encountered and for the handling of the inevitable borderline cases. At the same time the method should provide data which can be related not only to commercial standards as they exist at any time and place but also to the more important biological aspects.

That there is room for differences of opinion in this matter, especially as to objectives to be served in the harvest appraisal, is recognized. However, if the above statement of the ideal for an appraisal method is accepted, the writers believe that the method described in this paper, and tested in their four years' work as well as by several other workers, comes substantially close to it. The rating system allows the damage and to a considerable degree the infestation in each plot to be represented by a single figure, either the "damage index" or the "infestation index" which, as set forth, is a measure of the proportions of the roots in the different categories. It was found that these indices represent the sum of damage or of infestation much more precisely than does any other single figure, such as the percentage of clean or of "unmarketable" roots in a plot. The geometrical progression in the ratings represents the relative attack and damage more accurately than does an arithmetical one.

Certainly, there is very great advantage to be derived from agreement among the various workers on a common basic method of appraisal, making possible direct and accurate comparisons between the results obtained under the different conditions. This basic method may then be supplemented by anyone as he may deem desirable.

SUMMARY.—The results from three years' large-scale field experiments at four localities are here reported. Special discussion is given to the critical aspect of methods of appraising root maggot damage to rutabagas.

It is shown conclusively that practical effective control of root maggots on rutabagas is possible with some of the newer

insecticides, by the methods and under the conditions stated.

The method of application, to be both effective and economical, must maintain adequate amounts of the insecticide near the roots throughout the period of growth. The "band method," which has been proved to do this, has been successfully employed by commercial growers. The insecticide is applied in a narrow band and lightly covered with soil. The crop is then seeded along the center of the band. Spray applications to the crop, soon after it comes up and again as late in the growing period as is feasible, were effective and may become one of the most practical methods where suitable equipment is available. Application in the planting furrow with the seed has usually been effective but involves a greater risk of phytotoxicity. Dust applications to the growing crop were generally ineffective or unreliable.

Aldrin and heptachlor were the two most effective chemicals tested. Dieldrin, though effective, did not show sufficient advantage over aldrin to warrant its use. Chlordane, even at high rates, has not given adequate commercial control under conditions in coastal British Columbia. BHC was effective only at rates impractical because of the risk of off-flavor. DDT, lindane and parathion did not show promise as tested.

Suggested effective rates in terms of total toxicant per acre when rows are 3 feet apart, applied by the band, furrow, and spray methods, are 5, 2.5 and 5 pounds respectively for aldrin, and 5, 2.5 and 3 pounds for heptachlor. These rates apply to loam soils of average organic content.

## LITERATURE CITED


**Brooks, A. R.** 1951. Identification of the root maggots (Diptera: Anthomyiidae) attacking cruciferous garden crops in Canada, with notes on biology and control. Can. Ent. **83**(5): 109–20.

**Glendenning, R.** 1944. Root maggot control on turnips in the Pemberton area. Canada Dept. Agr. Entomological Lab., Agassiz, B.C. mim. leaflet.

**King, K. M.** 1949. The cabbage maggot. B. C. Dept. Agr. Hort. Cir. **32** (revised).

**King, K. M., R. Glendenning, and A. R. Forbes,** 1953. Root maggot control on swede turnips. Rept. B. C. Agronomists' Ass'n. Conf. 1953, 72.

**Morrison, H. E.,** and H. H. Crowell, 1952. Soil insecticide studies in Oregon. JOUR. ECON. ENT. **46**: 1002–10.

Officials of the Provincial and Dominion Depts. of Agr. 1949. Control of vegetable and field-crop pests and diseases. B. C. Dept. Agr. wall chart.

Officials of the Provincial and Canada Depts. of Agr. 1953. Control of vegetable and field-crop pests and diseases, 1953–54. B. C. Dept. Agr. wall chart.

**Oughton, J.** 1952. A study of turnip root maggots in Ontario. **82nd** Ann. Rept. Ent. Soc. Ont. 1951, 77–84.

**Stitt, L. L.** 1953. Insecticide tests for control of maggots in turnips. JOUR. ECON. ENT. **46**(2): 961–5.

# Control of Onion Thrips in the Winter Garden in 1953

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Experiments in onion thrips control were continued in 1953 to test new organic insecticides which are being developed continuously. Thrips damage in onions is usually severe each year; therefore the search for better control measures remains a major problem. Since the introduction of DDT as a thrips control in 1945, many organic insecticides and combinations of organic insecticides have been reported. Several new organic phosphate and chlorinated insecticides are good for controlling onion thrips as shown by Richardson & Wene (1952) and Richardson (1953) in reviews of the literature on the control of thrips.

Dieldrin, heptachlor and aldrin are the latest insecticides to give good control of onion thrips as reported by the following: Sloan & Rawlins (1951), Mayeux & Wene (1951), White *et al.* (1951),[2] Chapman (1952),[3] Merrill (1952), Richardson & Wene (1952), and Richardson (1953).

PROCEDURE.—The size of blocks available for this season's experiments limited the length of plots to 30 feet and the width to 18 rows. The plants were transplanted to 16-inch rows with 4-inch spacing.

Two organic insecticide experiments and one timing experiment were conducted. Treatments in all three experiments were replicated four times. Treatments in the time-interval experiment were applied at 7-, 14-, and 21-day intervals for specific numbers of times. All experiments were conducted on the Winter Garden Experiment Station farm.

Dusts were used in the first two experiments and a spray was used in the timing experiment. Dusts were applied with a hand duster at the rate of 15 to 22 pounds per acre. The spray was applied with a 3-gallon garden sprayer at the rate of 0.5 pound of heptachlor in 40 gallons of water per acre.

Records for the chlorinated hydrocarbon insecticide experiment were taken 1, 8, and 20 days after treatment; records for the phosphate insecticide experiment were taken 1, 8 and 16 days after treatment. Thrips population records for the timing experiment were taken at weekly intervals throughout the season. Yield records for this experiment were taken when the crop was harvested.

RESULTS AND CONCLUSIONS.—In table 1 the data indicate that several of the chlorinated hydrocarbons gave good commercial control. Five per cent heptachlor, 3-5-40[4] cotton dust, 2.5 per cent dieldrin, 2.5 per cent aldrin, 5 per cent CS-708, and the mixture of BHC (1 per cent gamma isomer) plus 5 per cent DDT gave satisfactory control of onion thrips 1 day after treatment. Eight days after treatment, 2.5 per cent dieldrin and 3-5-40 were considerably more effective and 5 per cent heptachlor was slightly more effective. Five per cent CS-708 and 20 per cent toxaphene remained about the same in effectiveness. The other materials were already decreasing in effectiveness. Two and one-half per cent dieldrin and 5 per cent heptachlor still gave extremely favorable residual control of onion thrips 20 days after treatment. The disparity between the second and third records on BHC (1 per cent gamma isomer) plus 5 per cent DDT mixture confirms the erratic results obtained in previous experiments. The following materials had little or no residual effect 20 days after treatment: 5 per cent Q-137, 2 per cent CS-708, 2.5 per cent aldrin, 2.5 per cent heptachlor, and 20 per cent toxaphene.

The data in table 2 show that all the phosphate insecticides and the mixture used as a standard gave excellent results 1 day after treatment. The order of effectiveness is as follows: 5 per cent malathion, 1 per cent methyl parathion, 2 per cent parathion, 1 per cent parathion, 1 per cent Metacide, 1 per cent BHC plus 5 per cent DDT, and 5 per cent EPN. Eight days after treatment, 2 per cent pa-

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[2] White, A. N., George P. Wene, and G. H. Godfrey. 1951. Guide for controlling insects and diseases on vegetable crops in the Lower Rio Grande Valley. Texas A&M College, Extension Work, and U. S. Department of Agriculture.

[3] Chapman, R. K. 1952. Vegetable insect control recommendations for 1952. Presented at Conference with Industry, Madison, Wisconsin.

[4] 3 per cent gamma isomer of BHC, 5 per cent DDT and 40 per cent sulphur—an extensively used cotton dust.

**Table 1.—Onion thrips per 10 plants in plots treated with chlorinated hydrocarbon dusts at the rate of 15 to 22 pounds per acre. Winter Haven, Texas, 1953.**

| Treatment | Days After Treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | | 8 | | 20 | |
| | Number of Thrips | Per Cent Reduction | Number of Thrips | Per Cent Reduction | Number of Thrips | Per Cent Reduction |
| Q-137, 5% | 11.0 | 57.7 | 78.5 | 51.8 | 369.5 | 0.0 |
| CS-708, 5% | 7.5 | 71.2 | 50.0 | 69.3 | 236.5 | 14.9 |
| CS-708, 2% | 11.3 | 56.5 | 87.0 | 46.6 | 278.8 | 0.0 |
| Heptachlor, 5% | 4.8 | 81.5 | 28.0 | 82.8 | 72.0 | 74.1 |
| Heptachlor, 2.5% | 10.3 | 60.4 | 70.8 | 56.6 | 221.5 | 20.3 |
| Aldrin, 2.5% | 8.3 | 68.1 | 62.5 | 61.7 | 237.0 | 14.7 |
| Dieldrin, 2.5% | 6.0 | 76.9 | 7.0 | 95.7 | 47.3 | 83.0 |
| Toxaphene, 20% | 10.0 | 61.5 | 52.5 | 67.8 | 186.3 | 33.0 |
| 3-5-40 cotton dust | 5.0 | 80.7 | 12.3 | 92.5 | 126.5 | 54.5 |
| BHC, 1% g.i., plus DDT, 5% | 9.0 | 65.4 | 154.3 | 5.3 | 126.0 | 54.7 |
| Untreated Check | 26.0 | | 163.0 | | 278.0 | |
| L.S.D. at 5% level | 14.1 | | 87.5 | | 104.3 | |
| at 1% level | 19.0 | | 117.9 | | 140.4 | |

rathion and 1 per cent methyl parathion were giving best control. One per cent Metacide was least residual and the remaining materials were giving only mediocre control. Five per cent EPN and 2 per cent parathion were still giving fair control 16 days after treatment.

In a timing experiment applications of insecticides were made at 7-, 14-, and 21-day intervals for specific numbers of times as shown in table 3. The percentage reduction in population for the season varies in proportion to the number of applications; but the yields do not vary in the same manner. It is interesting to note that entries 2, 4, and 5 give practically the same percentage reduction of thrips. The 3 applications at 7-day intervals was much less effective than any other treatment. Better control was obtained by seven ap-

**Table 3.—Effect of time interval and number of applications[1] on populations of onion thrips. Winter Haven, Texas. 1953.**

| Entry No. | Interval and No. of Applications | Population for the Season | | Yield, Bushels per Acre |
|---|---|---|---|---|
| | | Thrips per 10 Plants | Per Cent Reduction | |
| 1 | 7-day intervals (3 applications) | 323.3 | 61.8 | 493.3 |
| 2 | 7-day intervals (5 applications) | 154.3 | 81.8 | 583.7 |
| 3 | 7-day intervals (7 applications) | 77.3 | 90.9 | 506.4 |
| 4 | 14-day intervals (3 applications) | 169.8 | 80.0 | 520.0 |
| 5 | 14-day intervals (5 applications) | 107.8 | 87.3 | 578.8 |
| 6 | 21-day intervals (3 applications) | 161.5 | 80.9 | 487.9 |
| 7 | Untreated Check | 846.8 | | 458.5 |
| | L.S.D. at 5% level | 193.0 | | |
| | L.S.D. at 1% level | 264.4 | | |

[1] Each application made at rate of 0.5 pound of heptachlor in 40 gallons of water per acre.

**Table 2.—Onion thrips per 10 plants in plots treated with phosphate insecticide dusts at the rate of 15 to 22 pounds per acre. Winter Haven, Texas, 1953.**

| Treatment | Days After Treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | | 8 | | 16 | |
| | Number of Thrips | Per Cent Reduction | Number of Thrips | Per Cent Reduction | Number of Thrips | Per Cent Reduction |
| Methyl parathion, 1% | 30.0 | 92.4 | 83.3 | 73.3 | 326.0 | 51.2 |
| Metacide, 1% | 90.8 | 76.9 | 176.0 | 43.7 | 376.8 | 43.6 |
| Parathion, 1% | 68.0 | 82.7 | 112.8 | 63.9 | 359.0 | 46.3 |
| Parathion, 2% | 67.3 | 82.9 | 68.8 | 78.0 | 282.3 | 57.7 |
| EPN, 5% | 102.3 | 74.0 | 123.3 | 60.5 | 266.5 | 60.1 |
| Malathion, 5% | 25.3 | 93.6 | 130.8 | 58.1 | 372.5 | 44.2 |
| BHC, 1% g.i., plus DDT, 5% | 94.5 | 76.0 | 133.0 | 57.4 | 314.0 | 53.0 |
| Untreated Check | 393.5 | | 312.5 | | 668.0 | |
| L.S.D. at 5% level | 210.0 | | 134.1 | | 369.7 | |
| at 1% Level | 285.9 | | 182.5 | | 503.2 | |

plications at 7-day intervals and five applications at 14-day intervals. All entries gave commercial control based on the percentage reduction of thrips. It is probable that treatments made at 21-day intervals throughout the season would prove most economical and give sufficient control.

SUMMARY.—Several chlorinated hydrocarbon insecticides gave good commercial control of onion thrips. Two and one-half per cent dieldrin and 5 per cent heptachlor gave good residual control 20 days after treatment. A few other materials were fair in controlling onion thrips 8 days after treatment. Five per cent Q-137, 2 per cent CS-708, 2.5 per cent heptachlor and 20 per cent toxaphene did not compare favorably in effectiveness with 2.5 per cent dieldrin or 5 per cent heptachlor.

Of the phosphate insecticides, 2 per cent parathion and 1 per cent methyl parathion gave the best average reduction in population of onion thrips over a period of 16 days. Five per cent malathion gave high initial control but much less residual control. Other phosphates were less effective.

The timing treatments were all effective for the season except the one of three applications made at 7-day intervals. The treatment at 21-day intervals would be the most practical commercially. The yield data were apparently influenced by differences in soil type or other variable factors not accounted for in this experiment.

## LITERATURE CITED

**Mayeux, Herman S.**, and George P. Wene. 1950. Control of onion thrips with low volume sprays. JOUR. ECON. ENT. **43**(6): 908–12.

**Merrill, Leland G., Jr.** 1952. Relative effectiveness of various insecticides for control of onion thrips, under Michigan conditions. Quar. Bul., Mich. Agr. Expt. Sta. **34**(3): 238–44.

**Richardson, Ben H.**, and George P. Wene. 1952. Control of onion thrips in Texas. JOUR. ECON. ENT. **45**(2): 258–62.

**Richardson, Ben H.** 1953. Control of onion thrips in the Winter Garden area of Texas. JOUR. ECON. ENT. **46**(1): 92–5.

**Sloan, M. J.**, and W. A. Rawlins. 1951. Field trials in onion thrips control. JOUR. ECON. ENT. **44**(3): 294–301.

# A Trap for European Chafer Surveys

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During the last 12 years the European chafer, *Amphimallon majalis* Raz., has spread from the initial infestation at Newark, N. Y., over more than 550 square miles in a continuously infested area in western New York. The nightly flights of this beetle from the ground to tall trees for mating begin early in June; these flights are the most numerous during the latter part of June and early in July, and then decrease in number and density until early in August.

The extent of the infestation is determined by looking for flights of beetles during a 30-minute period at dusk. Beginning at a tree to which a flight has been observed, trees outside the known infested area are watched. By making nightly observations and finding beetles in flight around trees progressively farther away from the known infested area, it has been possible to extend the known infestation a few miles in one direction during the flight season. Surveys conducted in this manner have been made by H. P. Breitfeld and others of the New York State Department of Agriculture and Markets and by J. C. Silver of the Federal Bureau of Entomology and Plant Quarantine. However, there are definite limitations to this method of survey. A large staff is needed to make observations at many places, the flights last not more than 30 minutes, and inclement weather reduces the chances of seeing the beetles. There has been a need for a mechanical device, such as the traps used in making surveys for the Japanese beetle outside the areas of known infestation.

Preliminary experiments with traps have been carried on by several workers. In 1942 W. H. Whitcomb (unpublished

[1] The authors acknowledge the assistance of Cornell University entomologists F. L. Gambrell, stationed at Geneva, N. Y., and R. Burrage and G. Evans, at Ithaca, N. Y. Figures 1 and 2 were photographed by Miss Gertrude Catlin of the Geneva Station.

thesis, Cornell University) tested traps of various colors and also 30 attractants. In 1944 C. Logothetis (unpublished report, Cornell University) carried on experiments with traps of different sizes and in the placement of traps—in, near, under, and on trees. He also used grease and tanglefoot. In 1948 F. L. Gambrell, cooperating with J. C. Silver and P. J. McCabe of the Federal Bureau of Entomology and Plant Quarantine (unpublished report, New York Agricultural Experiment Station), baited traps with living European chafers and with extracts of the abdominal tips of virgin females.

Since 1949 the Bureau of Entomology and Plant Quarantine has been conducting experiments to develop attractive baits and traps for European chafers in areas of high population. This work was initiated by the late A. C. Mason. Three to five blocks of traps are operated during each flight season. Each block of 25 traps is arranged in a 5 by 5 Latin square with 20-foot intervals between the traps in the rows and columns. A row of unbaited barrier traps at a distance of 20 feet surrounds the test traps to reduce the heterogeneity in the captures throughout the Latin squares. The traps are hung on iron rods about 5 feet above the average ground level in the field.

TESTS WITH DIFFERENT BAITS.—In the study of liquid baits for attracting beetles, the baits were dispensed from a bottle and wick placed in standard or bucket-type Japanese beetle traps (Fig. 1). Traps of the same type and color were used throughout a Latin square. Tests were begun each week during the 5- to 6-week period of moderate to heavy flight. Each experimental block contained unbaited traps and traps with four test baits. The beetles were removed and counted at intervals during the week, and at the end of this period the total number captured by each trap was determined.

The preliminary tests in 1949 indicated that traps baited with several of the aromatic oils captured significantly more beetles than did the unbaited traps. Traps baited with Java citronella oil, for example, captured about three times as many beetles as the unbaited traps. The relative attractiveness of the aromatic baits tested from 1950 through 1953 is presented in table 1. The index of attractiveness for each material was determined in the following manner: The relative number of beetles captured by traps with each test bait as compared with the catch in unbaited traps in the test block was calculated. The relative value of each test bait was divided by the relative value of Java citronella oil and the quotient multiplied by 100. Java citronella oil was taken as the standard because it was the first bait to show promise and it has been tested

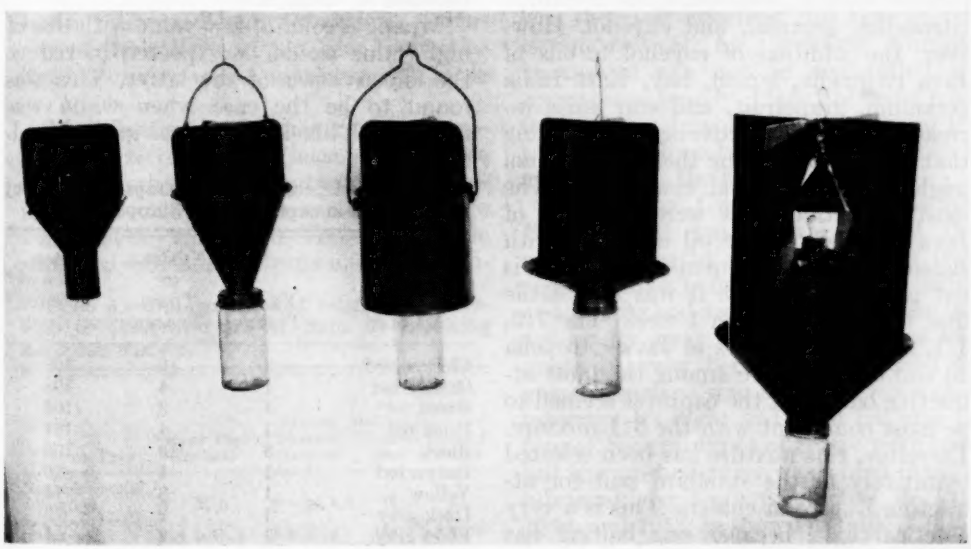

FIG. 1.—Types of traps tested for use in European chafer surveys, 1951–53. Left to right, Japanese beetle scouting trap, Japanese beetle standard trap, Japanese beetle bucket trap, European chafer trap, and June beetle trap.

**Table 1.—Attractiveness of baits to the European chafer.**

| Bait | Ratio of Components by Volume | Years Tested | Number of Times Tested | Mean Index of Attractiveness |
|---|---|---|---|---|
| Java citronella oil and eugenol | 7:3 | 1 | 2 | 120 |
| | 3:1 | 2 | 12 | 120 |
| Oil of lemon and eugenol | 9:1 | 2 | 6 | 112 |
| Java citronella oil and eugenol | 4:1 | 1 | 3 | 109 |
| Oil of lemon and eugenol | 3:1 | 1 | 2 | 108 |
| Java citronella oil and eugenol | 9:1 | 2 | 3 | 103 |
| Oil of lemon and eugenol | 1:1 | 1 | 2 | 101 |
| Java citronella oil | — | 3 | 15 | 100 |
| Java citronella oil and eugenol | 1:1 | 1 | 2 | 98 |
| Oil of bay and eugenol | 9:1 | 2 | 5 | 90 |
| Oil of lemon | — | 2 | 4 | 89 |
| Oil of East India geranium and eugenol | 9:1 | 1 | 4 | 87 |
| Citronellal | — | 1 | 2 | 84 |
| Geranyl acetate | — | 1 | 2 | 81 |
| Oil of orange | — | 1 | 2 | 81 |
| Citronellyl acetate | — | 1 | 3 | 79 |
| Oil of East India geranium | — | 2 | 4 | 78 |
| Oil of bay | — | 1 | 3 | 77 |
| Citronellol | — | 1 | 2 | 76 |
| Oil of grapefruit and eugnol | 9:1 | 1 | 2 | 73 |
| Hydroxycitronellol | — | 1 | 2 | 69 |
| Oil of orange and eugenol | 9:1 | 1 | 1 | 69 |
| Eugenol | — | 2 | 4 | 67 |
| Oil of grapefruit | — | 1 | 2 | 63 |
| Geraniol | — | 2 | 3 | 58 |
| Iso-eugenol | — | 1 | 1 | 56 |
| Oil and star anise and eugenol | — | 1 | 2 | 39 |
| Oil of star anise | — | 1 | 2 | 34 |
| Geraniol and eugenol | 9:1 | 1 | 1 | 23 |
| Unbaited | — | 3 | 22 | 32 |

the most extensively.

Java citronella oil was definitely more attractive than any of the components of this oil that were tested—citronellal, citronellyl acetate, geranyl acetate, hydroxycitronellol, geraniol, and eugenol. However, the addition of eugenol to oils of Java citronella, lemon, bay, East India geranium, grapefruit, and star anise increased their attractiveness, indicating that in baits containing these oils eugenol might be an essential component. The most attractive baits were mixtures of Java citronella oil or oil of lemon with eugenol. The oil of lemon-eugenol bait is not practical, because it was so volatile that it lasted less than 1 week. The 7:3, 3:1, and 4:1 mixtures of Java citronella oil and eugenol were among the most attractive baits, but the captures seemed to be most consistent with the 3:1 mixture. Therefore, this mixture has been selected tentatively as the standard bait for attracting European chafers. This is a very practical bait, because one baiting has lasted more than 3 weeks.

In 1951 and 1953 virgin females, field-collected females, and virgin males were confined in traps as bait for the beetles. The traps with virgin females 10 to 14 days old captured more beetles than those with virgin females less than 1 week old or with field-collected females. Traps baited with either male or female beetles caught about the same proportion of the sexes as did the unbaited traps or those containing the chemical baits. There was nothing to indicate that the captures by these traps were due to sex attraction. The traps baited with the living males or females were much less effective than those baited with the 3:1 Java citronella oil-eugenol mixture. Similar negative results were reported by Cambrell and coworkers in their preliminary work.

TESTS WITH TRAPS OF DIFFERENT COLORS.—Since the color of the trap was a factor influencing the number of Japanese beetles captured, it was assumed that it might be a factor with the European chafer. The influence of color on the effectiveness of the traps was tested in 1950, 1951, and 1953. A preliminary test in 1950 indicated that the effectiveness was in the ascending order of white, blue, yellow, red, and black, with red and black about equally effective. The black trap was used in subsequent years as the standard of comparison. In 1951 and 1953 traps painted with different glossy colors were tested in Latin squares. The relative effectiveness of traps of different colors is summarized in table 2.

Mixing a color of low value with one of high value would be expected to reduce the effectiveness of the latter. This was found to be the case when white was mixed with black to produce gray, or yel-

**Table 2.—Effectiveness of traps of different glossy colors in capturing the European chafer.**

| Color | Years Tested | Number of Times Tested | Mean Index of Attractiveness |
|---|---|---|---|
| Chinese red | 3 | 16 | 108 |
| Orange red | 1 | 4 | 108 |
| Green | 1 | 3 | 105 |
| Brick red | 1 | 4 | 101 |
| Black | 3 | 16 | 100 |
| Brown red | 1 | 4 | 80 |
| Yellow | 1 | 8 | 74 |
| Dark gray | 1 | 2 | 72 |
| Light gray | 1 | 2 | 57 |
| Orange | 1 | 1 | 55 |
| Blue | 1 | 8 | 44 |
| White | 1 | 8 | 30 |

low with red to produce orange, but a mixture of yellow and blue to produce green was more attractive than either of its components. In view of this incongruous result with green, further tests should be made with this color.

The Chinese-red and the orange-red traps consistently caught more beetles than the black traps, although the differences were not statistically significant. Since most of the experience has been with the Chinese red, it is believed that this color should be selected tentatively as the standard color for European chafer traps. Red traps are much more easily seen in the field, which is of practical advantage. Further tests were made with glossy and flat paints to determine whether the gloss was a factor. It was found that the traps with the glossy finish were far superior to the other traps in capturing beetles.

TESTS WITH DIFFERENT TYPES OF TRAPS.—The structure of the trap was found to be an important factor influencing the number of beetles captured. In 1951 four types of traps were tested—the June beetle trap borrowed from the Department of Entomology, Cornell University, and the scouting, bucket-type, and standard traps used in Japanese beetle work. In 1952 a special chafer trap was constructed with over-all dimensions slightly larger than the standard Japanese beetle trap but with a much larger baffle. These traps (Fig. 1), painted black, were arranged in Latin squares. Their dimensions, exclusive of the collection jars, and their relative effectiveness are summarized in table 3.

The effectiveness of the traps was proportional to their size. The small Japanese beetle scouting trap captured only one-eighth as many beetles as did the large June beetle trap. The Japanese beetle standard and bucket traps and the European chafer trap, which were intermediate in size, caught about one-third as many beetles. Although the June beetle trap was the most effective, this type of trap is impractical for scouting purposes because it can not be dismantled and transported readily. Plans are being made to develop a trap having the general features of the June beetle trap which can be assembled in the field.

**Table 3.—Dimensions and relative effectiveness of different types of traps in capturing European chafers.**

| TYPE OF TRAP | SIZE OF TRAP (INCHES) | SIZE OF BAFFLES (INCHES) | INDEX OF EFFECTIVENESS | |
|---|---|---|---|---|
| | | | Unmodified | Greased Baffles |
| Japanese beetle scouting | 6 × 8 | 3 × 4.5 | 12 | 31 |
| Japanese beetle standard | 7.5 × 11.5 | 2.5 × 4 | 30 | 35 |
| Japanese beetle bucket | 7.5 × 11.25 | 3.75 × 4 | 40 | 47 |
| European chafer | 9.25 × 12 | 4 × 9 | 35 | 61 |
| June beetle | 14 × 20 | 6 × 14 | 100 | 170 |

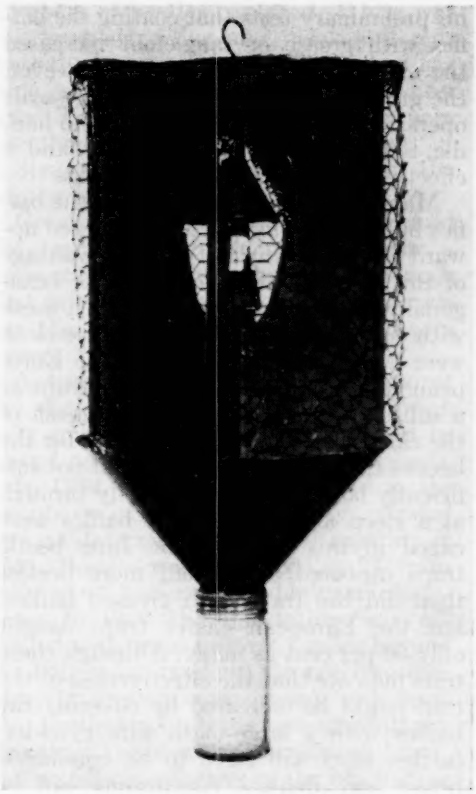

FIG. 2.—June beetle trap with wire cylinder.

EFFECT OF GREASING OR COVERING BAFFLES.—It has been observed that many beetles in flight touch the traps several times before they hit the baffles at an angle and are deflected into the funnel, or fly away. When the baffles were greased, every beetle that touched the greased surface was held long enough to interrupt its flight so that it fell into the funnel. Several types of grease were tried, but the most effective was a high-pressure lubricant. In tests conducted in 1951, 1952, and 1953, as shown in table 3, it was found that greasing the baffles increased the number of beetles captured in all types of traps. Logothetis also found in

his preliminary tests that coating the baffles with grease or tanglefoot increased the effectiveness of the traps. However, the grease is impractical for a large-scale operation because it is unpleasant to handle, is slow and laborious to apply, and is effective for not more than 3 weeks.

Many beetles flew straight into the baffles but before making contact verged upward at a steep angle. To take advantage of this habit of flight, cylinders of hexagonal-weave chicken wire of 1-inch mesh with tops of ½-inch mesh hardware cloth were fitted over the baffles of the European chafer and the June beetle traps as a substitute for the grease. The mesh of the chicken wire was large enough for the beetles to fly straight through but not sufficiently large that they could fly through at a steep angle. When the baffles were caged in this manner, the June beetle traps captured 60 percent more beetles than did the traps with greased baffles, but the European chafer traps caught only 80 per cent as many. Although these tests indicate that the effectiveness of the trap might be increased by covering the baffles with a large-mesh wire cylinder, further tests will have to be conducted before any definite conclusions can be drawn.

PLACING TRAPS.—The European chafer will fly to any object that is silhouetted against the sky, but it is attracted more to trees than to inanimate objects. Traps were placed at 100-foot intervals up the southern slope of a drumlin. Position 1 was at the bottom of the drumlin, position 3 at the crest of the first small rise with the area to position 4 in the same contour, and position 7 at the main crest of the drumlin with no rise to position 12, which was within 50 feet of tall trees.

The trap in position 3 consistently caught more beetles than the other traps. When the numbers taken in the other traps were compared with the number captured by this trap, the relative effectiveness of the traps in each position can be expressed on a percentage basis, as follows:

| *Position* | *Per Cent Effectiveness* | *Position* | *Per Cent Effectiveness* |
|---|---|---|---|
| 1 | 47 | 7 | 41 |
| 2 | 54 | 8 | 28 |
| 3 | 100 | 9 | 23 |
| 4 | 69 | 10 | 17 |
| 5 | 67 | 11 | 3 |
| 6 | 66 | 12 | 2 |

The number of beetles captured increased progressively up the slope to the crest of the first small rise and then decreased as the traps approached the large trees on the top of the drumlin. It was evident that the most favorable position for a trap was where it was silhouetted against the sky and was not in competition with large trees. Placing traps in competition with large trees should be avoided. It is not always possible to avoid placing traps in competition with small trees and shrubs. In this case the prevailing direction of the wind is an important factor. Traps on the leeward side of the plants invariably captured more beetles than those on the windward side.

TRAPS FOR SCOUTING IN LIGHTLY INFESTED AREAS.—In a preliminary test in 1951, 43 Japanese beetle standard traps, painted black, were placed along the periphery of the continuously infested area as determined by visual scouting in 1950. Five of these traps caught beetles in this lightly infested area.

In 1952 a total of 365 Japanese beetle bucket traps, painted black with greased baffles and baited with a 3:1 mixture of Java citronella oil and eugenol, were placed around the continuously infested area as determined by visual scouting in 1951. The traps were at positions from 1.5 miles within the known limits of the 1951 flight up to 5 miles beyond these limits. They were placed in the higher parts of pastures, golf courses, cemeteries, and abandoned fields where there was a good growth of permanent grass, and in alfalfa and clover fields after the crops had been harvested. So far as possible the traps were silhouetted against the sky. When it was necessary to place a trap near an isolated shrub, it was placed on the east, which was the leeward side. The traps were left in position for 5 or 6 weeks. At the end of this time the wicks in the bait bottles were still saturated and a small amount of bait remained. Beetles were captured in 71 of these traps within the known limits of the 1951 infestation and up to 3.7 miles beyond it. The discovery of new infestations by trapping closely paralleled the results obtained by visual scouting.

In 1953 neither the traps nor the manpower was available for placing traps in a zone 5 miles wide completely around the boundary of the infestation determined in

1952. Traps were set in this manner along the northwestern edge and in a small section on the eastern side. Of the 114 traps placed in these positions, the European chafer was captured in 34 of them. None were taken in traps beyond the eastern edge of the known infestation, but on the northwestern side the infestation was extended 2.7 miles beyond the known limits of the 1952 infestation.

In the lightly infested areas major emphasis was placed on the comparison of black bucket, red bucket, and black June beetle traps. One trap of each type was placed in 23 locations. A total of 43 beetles were taken in 14 of these locations during the season, 7 in 6 black bucket traps, 19 in 13 red bucket traps, and 17 in 14 black June beetle traps. From the limited comparisons that could be made, it appears that painting the Japanese beetle bucket trap red made it as effective as the black June beetle trap.

SUMMARY.—The European chafer, *Amphimallon majalis* Raz., has spread during the last 12 years over 550 square miles in western New York. Progress made in developing a trap for scouting for this beetle outside the known infested areas is summarized briefly.

Java citronella oil as a bait was more attractive to chafers than six of its components. Most attractive baits were mixtures of Java citronella oil or lemon oil with eugenol, but lemon oil was too volatile to be practical. Java citronella oil-eugenol mixture, 3:1 by volume, has been selected tentatively as the best bait.

Virgin males and females placed in traps were not attractive to beetles.

The color of the trap influenced the numbers of beetles captured. White was the least attractive and black and reds were the most attractive. Chinese red has been selected tentatively as the best color. Traps with a glossy finish were more effective than those with a dull finish.

Structurally the effectiveness of the trap was proportional to its size.

Greasing the baffles of traps increased the captures, but is impractical for a large-scale operation. There was evidence that catches might be increased by covering the baffles with a large-mesh wire screen.

A trap should be silhouetted against the sky and away from tall trees. When near small trees or shrubs, it should be placed on the leeward side of the plants.

In 1952, 365 traps were placed in the periphery of the continuously infested area as determined by visual scouting in 1951. Beetles were captured in 71 traps and up to 3.7 miles beyond known infestations. In 1953 the infestation was extended with traps up to 2.7 miles beyond the known limits along the northwestern edge. In limited comparisons, red Japanese beetle bucket traps were more attractive than the same traps painted black, and equally as effective as the black June beetle traps.

Scouting with traps was equally as effective as visual scouting in finding light infestations.

Encouraging as the results have been in the use of traps, the bait and the construction must be considered still to be in the developmental stage. Further research is needed to increase its efficiency in capturing beetles.

# Spray Mixtures to Control Putnam Scale and Bark Beetles on Elms

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There have been many references to Putnam scale, *Aspidiotus ancylus* (Putn.), indicating its wide host range and extensive distribution in the United States. Evidently it has been of relatively little economic importance as compared with San Jose scale, *A. perniciosus* Comst. Pettit (1898) and Forbes (1911) reported that Putnam scale was seldom troublesome. On the other hand Johnson (1896) observed dead limbs and branches on an English oak, *Quercus robur* L., because of ravages of this scale, and Houser (1908) noted severe damage to hard maple and linden in the parks and along the streets of Cleveland, Ohio. According to Felt (1901) nearly every tree in a young apple orchard in Massachusetts was dying from its effects. Considerable damage by Putnam scale has occurred on cranberries (Scammell 1917) and blueberries (Darrow 1944).

Damage by Putnam scale to elms on the campus of the University of Illinois was observed in the spring of 1952. Inspection of trees indicated rather general, and on some trees severe, damage. These observations were corroborated by classifying and weighing the dead wood prunings from 13 consecutive trees in a block. The wood showing evidence of a heavy scale infestation comprised 62 per cent, by weight, of the total prunings.

In 1949 a spray program was initiated on the University campus to control the vector, *Scaphoideus luteolus* Van D., of phloem necrosis, a virus disease of elms. This program called for two foliar applications of 6 per cent DDT emulsion by mist blower (Swingle *et al.* 1949). The dosage approximated 1 pound actual DDT per tree per application for some 2,000 medium to large trees. In view of the fact that DDT was known to increase populations of *Lecanium pruniosum* (Michelbacher *et al.* 1946), *Chrysomphalus aonidum* (Griffiths & Thompson 1947), and *Aspidiotus forbesi* (Chandler 1950), among others, the DDT applications on elms were suspected of having something to do with the Putnam scale infestations. Accordingly, an intensive survey of the scale insect infestations of both sprayed and unsprayed elms on the campus and in the twin cities of Urbana-Champaign was made. Samples of live and dead wood were pruned by a climber from 89 trees. Thirty-one of the trees had not been sprayed, 10 had been sprayed twice, 28 four times, and 20 six times. There was an almost linear correlation between the number of DDT applications and the infestation ratings. Putnam scale was hard to find on unsprayed trees, without exception, and only by persistent effort could a few specimens be found on the samples from these trees. On trees sprayed six times in three years the infestations ranged from moderate to heavy.

Several chalcid parasites have been found to be an important factor in the control of Putnam scale under natural conditions, and the effect of DDT on these parasites is the object of a detailed study, which will be reported later.

Control Measures.—During the summer of 1952, DDT sprays were supplemented with malathion, with NPD,[1] and with powdered cubé containing 5 per cent rotenone on small plots of trees. These three mixtures gave essentially no control of Putnam scale. In 1953 an increase in the incidence of Dutch elm disease in the community indicated the need to revise the spray program to include a pre-foliar application of DDT for control of the bark beetles that disseminate the disease fungus, *Ceratostomella ulmi* (Schwarz) Baisman. With a critical scale infestation and the need for expanding the DDT spray program it became necessary to try to integrate the disease control and the scale control measures.

The program for control of Dutch elm disease includes either a 2 per cent DDT emulsion spray applied with hydraulic equipment, or a 12 per cent DDT emulsion applied with a mist blower before growth starts in the spring (Swingle *et al.* 1949). The usual recommendation for scale control is the application of a dor-

[1] DuPont's 85 per cent emulsifiable tetra-N-propyl dithionopyrophosphate.

mant oil spray with hydraulic equipment, also before growth starts. Because of the height of some of the trees it was desirable to utilize the mist blower for both the DDT and the dormant oil. However, there was little experimental background for mist blower applications of dormant oil, and apparently no information on the application of mixtures of dormant oil and DDT. Therefore, an experiment was designed to determine:

1. If Putnam scale could be controlled with mist blower applications of dormant oil.
2. If DDT emulsions could be mixed with the dormant oil to control both scale and bark beetles in one treatment by hydraulic application and/or mist blower application without reducing the effectiveness of either or injuring the trees.

PROCEDURE.—Thirteen plots of trees were selected so that there would be a minimum of spray drift from one to the other. The trees were all in the same area of the campus. One plot contained four record trees, but all others contained five. In some plots the record trees comprised the entire plot, in others there were a number of buffer trees.

The mist-blower type of sprayer used was a John Bean Roto-Mist, Model L-926, which delivered 24,800 cubic feet of air per minute at a velocity of 90 m.p.h. The liquid spray was discharged into this air blast at the rate of 1.5 to 2 gallons per minute. The hydraulic sprayer was a John Bean Royal, Model 35, with power take-off. The spray gun used with this sprayer had a 12/64-inch aperture and was operated by the spraymen from the top of the sprayer.

Plot 7 received an average of 3 gallons of spray per tree. Although the same time and care were used in spraying this plot as the others, the discharge rate apparently was reduced because of the viscous and syrupy nature of the spray mixture, which contained a relatively low proportion of water. The other plots sprayed with the mist blower received from 5 to 9 gallons per tree. Those sprayed with the hydraulic machine received from 47 to 75 gallons per tree.

Both the mixing and spraying operations were carefully supervised. Trees were sprayed on opposite sides under practically still atmospheric conditions. The applications were started March 27 and completed April 23.

MATERIALS.—The oil spray manufactured by the Standard Oil Company of Indiana was Dormant Spray Oil No. 1 (Dendrol) which contained:

| | |
|---|---|
| Petroleum oil | 90.34% |
| Petroleum sulfonates | 7.86% |
| Inert ingredients | 1.80% |

Also manufactured by the Standard Oil Company was a DDT emulsion known as Elm Spray-Emulsifiable Concentrate, which contained:

| | |
|---|---|
| DDT | 25% |
| Petroleum oil—a paraffinic technical white oil | 18% |
| Petroleum xylene and related compounds | 55% |
| Inert ingredients | 2% |

The other DDT emulsion was Geigy Company's E-25, containing:

| | |
|---|---|
| DDT | 25% |
| Xylene | 63% |
| Aromatic petroleum solvent | 7% |
| Inert | 5% |

The mixing procedure was to fill the spray tank about one-third full of water, start the agitator, add the Dendrol, then add the DDT. No compatability trouble developed except with the Standard Oil Company's DDT concentrate. In spite of the fact that mixing sequences had been carefully worked out in the laboratory, a curdy precipitate developed when this material was agitated in the spray tank with Dendrol. Tests indicated that the temperature (about 50° F.) of the water had something to do with this trouble. The precipitate appeared to have little effect on the results, however.

RECORDS.—Ten branches about 1 inch in diameter were cut at random by a climber from each record tree in March for pre-treatment scale counts. These samples indicated a rather uniform infestation, and counts of 1,000 scales from each tree gave a range of 46 to 58 per cent dead.

Beginning June 1, samples were taken again and scale counts were made in the same manner. In addition to twigs for scale counts, half-inch twigs about 12 inches long were taken for bark beetle feeding tests. Also, twig samples were taken for DDT residue analyses.

*Results on Putnam Scale.*—There was no significant difference in the kill of scale between two DDT formulations mixed with Dendrol and applied with a hydraulic sprayer (Plots 1 and 2, Table 1). Both treatments gave very good kills. For some

**Table 1.—Spray treatments against Putnam scale and smaller European elm bark beetles, together with DDT residues.**

| Plot No. | Treatment | Sprayer[5] | Per Cent Dead Scales | Bark Beetle Scars[6] | DDT Residues[7] |
|---|---|---|---|---|---|
| 1 | Dendrol 4% mixed with DDT 2%[1] | Hy | 94.1 | 1.2 | 32.0 |
| 2 | Dendrol 4% mixed with DDT 2%[2] | Hy | 98.8 | 0.2 | 55.2 |
| 3 | Dendrol 4% followed by DDT 2%[2] | Hy | 85.3 | 0.0 | 84.5 |
| 4 | Dendrol 4% (Hy) followed by DDT 12%[2] (MB) | | 97.2 | 0.0 | 239.6 |
| 5 | DDT 12%[2] | MB | 84.9 | 0.6 | 211.4 |
| 6 | Dendrol 24% | MB | 91.3 | 13.8 | 11.1 |
| 7 | Dendrol 24% mixed with DDT 12%[3] | MB | 95.9 | 2.2 | 77.5 |
| 8 | Dendrol 24% mixed with DDT 6%[2] | MB | 97.2 | 4.0 | 49.2 |
| 11 | Dendrol 12% mixed with DDT 6%[2] | MB | 98.3 | 3.2 | 90.0 |
| 9 | Dendrol 24% containing DDT 2%[3] | MB | 99.6 | 10.0 | 15.8 |
| 10 | Dendrol 24% mixed with DDT 3%[4] | MB | 84.1 | 3.2 | 27.4 |
| 12 | Control (no spray for 2 years) | | 91.0 | 29.8 | 2.4 |
| 13 | Control (no dormant oil) | | 78.8 | | |
| | Least significant difference at 5% level | | 7.2 | 6.8 | 46.7 |

[1] Standard Oil Co's. elm tree spray containing white oil and 25% DDT.
[2] Geigy's E-25, containing 25% DDT.
[3] Technical DDT "dissolved" in Dendrol.
[4] DDT in a wettable powder.
[5] Hy, hydraulic; MB, mist blower.
[6] Average per tree sample.
[7] Mg. DDT per 1,000 sq. cm. twig, average per tree sample.

reason a hydraulic application of Dendrol followed in 2 weeks by a hydraulic application of 2 per cent DDT[2] was not as effective as a hydraulic application of Dendrol followed by a mist blower application of 12 per cent DDT (Plots 3 and 4).

On plots treated entirely with the mist blower, the kill with 12 per cent DDT was not significantly different from that in the control (Plots 5 and 13). There was no significant difference in kill among plots 6, 7, 8, and 11, where Dendrol was used alone and where mixed with DDT. Of further interest is the fact that 12 per cent Dendrol mixed with 6 per cent DDT was just as effective as Dendrol and DDT at twice these concentrations (Plots 11 and 7). DDT wettable powder mixed with Dendrol apparently was not as effective as Dendrol alone (Plots 10 and 6). The 91 per cent mortality produced by natural agencies on plot 12 (unsprayed for 2 years) was almost identical with the mortality obtained by spraying with 24 per cent Dendrol by mist blower.

*Bark Beetle Feeding Tests.*—Twigs for these tests were taken from the tree samples, promptly placed in plastic bags, and shipped by parcel post to Columbus, Ohio, where feeding tests were made as follows: Ten twigs from each of these samples were selected for uniformity of growth and these were confined in a ventilated half-gallon fruit jar with 25 adult smaller European elm bark beetles, *Scolytus multistriatus* (Marsh.). When all of the beetles were dead the twigs were removed and examined for feeding scars with the aid of a binocular microscope.

It will be observed that the number of feeding scars on all sprayed plots was significantly lower than on the control (Table 1). Two foliar applications of DDT each summer for 4 years left an accumulated residue of 22 to 28 milligrams of DDT per 1,000 square centimeters on two- and three-year old wood, as determined from analyses made in March.

On plot 6, which received no DDT in 1953, there was a DDT residue of 11.1 milligrams per 1,000 square centimeters of twig from previous treatments. This residue held the number of feeding scars to an average of 13.8 as compared to 29.8 on the control plot, which had received no DDT for 2 years. Plot 9 received a low dosage of DDT and was significantly higher in feeding scars than most of the other treated plots. There appeared to be no significant differences among the other nine treated plots. There was no essential difference between the number of feeding scars on samples from trees sprayed with Dendrol mixed with 6 per cent DDT and Dendrol mixed with 12 per cent DDT.

*DDT Residues.*—About 20 fairly straight twigs, 0.5 to 1.0 centimeter in di-

[2] Percentages of DDT are actual. The 2 per cent spray contained 8 gallons of 25 per cent DDT emulsion per 100 gallons of spray; the 12 per cent, 48 gallons of emulsion per 100 of spray

ameter and 15 to 20 centimeters long, were taken from the tree samples for DDT analyses. The DDT was extracted from each sample in a half-gallon fruit jar with 300 milliliters of hexane by rotating the jars endwise in a special machine for 30 minutes. The extracts were adjusted for recovery and analyzed for DDT by the Volhard titration method. After extraction, each twig was measured with a centimeter caliper near the middle for diameter and with a centimeter rule for length. From these measurements the surfaces of the samples were calculated.

The most obvious conclusion is that a much greater residue was obtained with mist blower applications of DDT alone than with a mixture of DDT and Dendrol (Table 1). This difference in residues was not significant when hydraulic equipment was used to apply the same materials at the usual concentrations (Plots 2 and 3). There was little difference between residues left by mixtures of Dendrol and DDT applied by hydraulic sprayer and residues left by Dendrol and DDT applied by mist blower, even though the concentration of the latter was six times that of the former.

SUMMARY.—Elm trees were sprayed with a dormant oil and a DDT emulsion for the control of Putnam scale and smaller European elm bark beetles. The sprays were applied separately and as mixtures by hydraulic and mist blower equipment. The following programs show promise for the control of both pests:

1. Dendrol 4% mixed with DDT 2% (hydraulic)
2. Dendrol 4% (hydraulic) followed by DDT 12% (mist blower)
3. Dendrol 24% mixed with DDT 12% (mist blower)
4. Dendrol 24% mixed with DDT 6% (mist blower)
5. Dendrol 12% mixed with DDT 6% (mist blower)

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## LITERATURE CITED

**Chandler, S. C.** 1950. Forbes scale as a major pest of peach. JOUR. ECON. ENT. **43**(3): 398.

**Darrow, George M.,** R. B. Wilcox, and Charles S. Beckwith. 1944. Blueberry growing. U. S. Dept. Agr. Farmers' Bul. **1951.**

**Felt, Ephriam Porter.** 1901. Scale insects of importance. N. Y. State Museum Bul. **46,** Vol. 9: 326.

**Forbes, Stephen A.** 1911. Some important insects of Illinois shade trees and shrubs. Ill. Agr. Expt. Sta. Bul. **151:** 523.

**Griffiths, James T., Jr.,** and W. L. Thompson. 1947. The use of DDT on citrus trees in Florida. JOUR. ECON. ENT. **40**(3): 386.

**Houser, J. S.** 1908. The more important insects affecting Ohio shade trees. Ohio Agr. Expt. Sta. Bul. **194:** 176.

**Johnson, W. G.** 1896. Notes on new and old scales. U. S. Dept. Agr. Div. Ent. Bul. **6,** n.s., p. 76.

**Michelbacher, A. E.,** Clark Swanson, and W. W. Middlekauff. 1946. Increase in the population of ***Lecanium pruniosum*** on English walnuts following applications of DDT sprays. JOUR. ECON. ENT. **39**(6): 812.

**Pettit, Rufus H.** 1898. Some insects of the year 1897. Mich. Agr. Expt. Sta. Bul. **160:** 414.

**Scammell, H. B.** 1917. Cranberry insect problems and suggestions for solving them. U. S. Dept. Agr. Farmers' Bul. **860.**

**Swingle, R. U.,** R. R. Whitten, and H. C. Young. 1949. The identification and control of elm phloem necrosis and Dutch elm disease. Ohio Agr. Expt. Sta. Sp. Cir. **80.**

# The Toxicity of Phosphoric Acid Esters to Anopheline Larvae[1]

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During recent years organic phosphorus compounds have received considerable attention from economic entomologists, largely because of their effectiveness against insects resistant to the chlorinated hydrocarbons. A number of the phosphorus compounds have been in general use for several years, and as yet no detrimental degree of resistance to them has been reported. The search is being continued for compounds in this group that are less toxic to warm-blooded animals or can be used at lower dosages.

Several phosphorus compounds, particularly EPN and malathion, have been reported as effective mosquito larvicides, and are in limited use for the control of culicine larvae that have become highly resistant to chlorinated hydrocarbons. As yet no serious problem of resistance has been reported in anopheline larvae, even in areas that have been intensively treated with DDT and related compounds, but it is possible that resistance will increase to such a degree that the larvicides presently in use will no longer be effective.

In view of this possibility, studies were undertaken at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine to evaluate the available esters of phosphoric acid for toxicity to anopheline larvae. Of 274 compounds screened in the laboratory, only 14 showed sufficient toxicity to warrant testing in the field. Results of the laboratory and field tests with this small group of compounds are presented in this paper.

Laboratory Tests.—Screening tests were conducted in the laboratory against fourth-instar larvae of *Anopheles quadrimaculatus* Say. Acetone solutions of the toxicants were introduced into distilled water at concentrations ranging from 0.1 to 0.0005 p.p.m. of the toxicant. Distilled water was used to avoid the effects of suspended matter and dissolved chemicals that occur in other types of water. From 2 to 4 replicate lots of 25 larvae each were exposed to each concentration, and mortality counts were made after 24 and 48 hours. The results with the 14 most effective phosphorus compounds and DDT are given in table 1.

Sulfotepp, parathion, and EPN were about equally effective and were the most toxic materials tested, although only slightly more toxic than methyl parathion. DDT was less toxic than these materials but was at least equal to the other phosphorus compounds. Malathion, Diazinon, and para-oxon were of intermediate toxicity, whereas Potasan, *O,O*-diethyl *O*-piperonyl thiophosphate, and NPD were the least toxic.

Field Tests.—Field tests with the 14 most effective phosphorus compounds and DDT were conducted on plots 200 square feet in area. The plots were located in drainage ditches and roadside borrow pits that were generally choked with water hyacinths, water lilies, and grass. All larval stages of *Anopheles crucians* Wied. and *quadrimaculatus* were present, the former predominating. Larval populations in the plots, as determined by dipping counts, averaged from 0.8 to 44 per dip before treatment. The effectiveness of the various treatments was based on the reduction in larval counts after 24 hours.

The insecticides were applied in emulsions at dosages ranging from 0.25 to 0.001 pound per acre. Applications were made with a small hand atomizer, which produced very fine particles, at a standard rate of 5 pints per acre. Different dosages were obtained by varying the concentration of the insecticides in the sprays. From 3 to 11 replications were made with each dosage. Results of the tests are summarized in table 2.

EPN, *O*-(3-chloro-4-methylumbelliferone) *O,O*-dimethyl thiophosphate, parathion, and DDT were about equally effective and were substantially more toxic than any of the other materials at low dosages. Methyl parathion, Diazinon, paraoxon, and NPD were representative of materials of intermediate toxicity, whereas sulfotepp, malathion, and Potasan showed the least promise.

A comparison of the results of labora-

[1] Presented at the meeting of the Entomological Society of America, Los Angeles, Calif., December 7–10, 1953. This work was conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine under funds allotted to the Bureau by the Department of the Army.

**Table 1.—Toxicity of phosphoric acid esters in acetone-water suspensions to fourth-instar larvae of *Anopheles quadrimaculatus*. (Laboratory tests.)**

| Compound | Per Cent Mortality in 48 Hours at Indicated Concentration (p.p.m.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.1 | 0.05 | 0.025 | 0.01 | 0.005 | 0.0025 | 0.001 | 0.0005 |
| Sulfotepp | 100 | 100 | 100 | 100 | 100 | 100 | 74 | 34 |
| Parathion | 100 | 100 | 100 | 100 | 100 | 96 | 56 | 34 |
| EPN | 100 | 100 | 100 | 100 | 100 | 96 | 32 | — |
| Methyl parathion | 100 | 100 | 100 | 100 | 100 | 67 | — | — |
| *O*-(2-Chloro-4-nitrophenyl) *O,O*-dimethyl thiophosphate | 100 | 100 | 100 | 96 | 86 | 62 | 62 | 44 |
| Malathion | 100 | 100 | 96 | 80 | 80 | 60 | 40 | 24 |
| Ethyl *o*-nitrophenyl thionobenzene-phosphonate | 100 | 100 | 100 | 100 | 70 | 80 | 4 | — |
| Diazinon[1] | 100 | 100 | 100 | 100 | 36 | 20 | — | — |
| Para-oxon | 100 | 100 | 100 | 82 | 50 | — | — | — |
| *O*-(3-Chloro-4-methylumbelliferone) *O,O*-dimethyl thiophosphate | 100 | 100 | 100 | 64 | 46 | 24 | — | — |
| Chlorthion[2] | 100 | 100 | 88 | 76 | 44 | — | — | — |
| Potasan[3] | 100 | 98 | 56 | 30 | 5 | — | — | — |
| *O,O*-Diethyl *O*-piperonyl thiophosphate | 100 | 94 | 58 | 26 | — | — | — | — |
| NPD[4] | 94 | — | 62 | 30 | — | — | — | — |
| DDT (check) | — | — | — | 100 | 94 | 49 | 24 | — |

[1] *O,O*-Diethyl *O*-(2-isopropyl-6-methyl-4-pyrimidinyl) thiophosphate.
[2] *O*-(3-Chloro-4-nitrophenyl) *O,O*-dimethyl thiophosphate.
[3] 4-Methylumbelliferone *O,O*-diethyl thiophosphate.
[4] Tetra-*n*-propyl dithionopyrophosphate.

**Table 2.—Effectiveness of emulsions of phosphoric acid esters against larvae of *Anopheles crucians* and *A. quadrimaculatus*. (Field tests.)**

| Compound | Per Cent Mortality in 24 Hours at Indicated Dosage (Pound per Acre) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.25 | 0.1 | 0.05 | 0.025 | 0.01 | 0.005 | 0.0025 | 0.001 |
| EPN | — | — | 95 | 96 | 96 | 95 | 92 | 91 |
| *O*-(3-Chloro-4-methylumbelliferone) *O,O*-dimethyl thiophosphate | — | — | 98 | 98 | 99 | 96 | 91 | 84 |
| Parathion | — | — | 97 | 97 | 92 | 99 | 88 | — |
| Methyl parathion | — | 100 | 98 | 83 | 69 | 51 | 50 | — |
| Ethyl *o*-nitrophenyl thionobenzene-phosphonate | — | 99 | 80 | 88 | 75 | 70 | 69 | 71 |
| Chlorthion | 100 | 99 | 82 | 73 | 57 | 50 | — | — |
| Diazinon | — | 97 | 97 | 79 | 58 | 65 | 55 | 53 |
| *O*-(2-Chloro-4-nitrophenyl) *O,O*-dimethyl thiophosphate | — | 99 | 72 | 78 | 49 | 30 | — | — |
| NPD | 100 | 97 | 84 | 87 | 79 | — | — | — |
| Para-oxon | — | 90 | 77 | 54 | 46 | 45 | 49 | 31 |
| Sulfotepp | — | 85 | 72 | 73 | 63 | 53 | 30 | — |
| Malathion | 90 | 78 | 79 | 68 | 60 | — | — | — |
| *O,O*-Diethyl *O*-piperonyl thiophosphate | — | — | 78 | 64 | 75 | 74 | 45 | 35 |
| Potasan | — | 77 | 59 | 72 | 52 | — | — | — |
| DDT (check) | — | — | 99 | 98 | 99 | 98 | 95 | 92 |

tory and field tests showed marked differences in the relative effectiveness of malathion, sulfotepp, and *O*-(3-chloro-4-methylumbelliferone) *O,O*-dimethyl thiophosphate. The other materials maintained about the same relative toxicity in both types of tests.

SUMMARY.—A total of 274 phosphoric acid esters were tested in the laboratory against larvae of *Anopheles quadrimaculatus* Say. Only 14 compounds showed sufficient promise to warrant field testing. Sulfotepp, parathion, and EPN were about equally toxic and were the most effective phosphorus compounds. They were also superior to DDT. Malathion, Diazinon, and para-oxon were of intermediate effectiveness. Potasan, *O,O*-di-

ethyl *O*-piperonyl thiophosphate, and NPD were the least effective compounds. In field tests against *A. crucians* Wied. and *quadrimaculatus* EPN, *O*-(3-chloro-4-methylumbelliferone) *O,O*-dimethyl thiophosphate, parathion, and DDT were the most effective materials tested. All were substantially more toxic than the other compounds.

## Teosinte as a Host for Stored Grain Insects[1]

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Workers concerned with implementing the vegetable diet of people living in the tropical zone of the Americas have been interested in teosinte, *Euchlaena* sp., as a possible source of protein and essential amino acids (Melhus & Scrinshaw 1953). Furthermore, plant breeders are using teosinte as a source of germ plasm in breeding programs to develop disease and pest-resistant strains of corn to which it is the closest known relative (Weston 1929, Reeves 1950). Food manufacturers are exploring its possibilities as a breakfast cereal. It also is being proposed as an alternate crop in a rotation program on rice land in Texas. Since little, if anything, was known relative to teosinte grain as a host of stored grain pests, a simple test to determine its acceptability as a host to some of the more common stored grain pests was conducted.

METHODS.—Samples of hulled and unhulled teosinte were acquired from Guatemala.[3] The kernel is smaller than corn and is enclosed in a hard, tight fitting hull. During the process of removing the hull, many of the kernels were broken so that hulled grain consisted of kernel fragments as well as whole kernels. The samples of hulled and unhulled grain each were divided into 3 sub-samples, and each sub-sample placed in an unsized muslin bag, $4\frac{1}{2} \times 6$ inches in dimensions. Each bag of grain was dipped briefly into a basin of water to wet the cloth, thereby facilitating passage of atmospheric moisture through it. The sub-samples of hulled and unhulled grain were placed in barrels of bulk grain (corn) in which the percentage of moisture had previously been adjusted to 15, 18, and 21 per cent.

The teosinte grain was removed from the barrels of bulk corn after a stabilization period of 6 weeks at the respective moisture levels. At the end of the moisture stabilization period, the sub-samples of hulled and unhulled grain were divided into 10-gram lots and each lot placed in a 75-ml. bottle with a plastic screw cap. Twenty-five unsexed, 40 to 50 day old adults of flat grain beetles, *Laemophloeus* sp., saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.), red flour beetle, *Tribolium castaneum* (Hbst.), and confused flour beetle, *Tribolium confusum* Duv. were introduced into bottles of hulled teosinte at each of the three moisture levels. The different species were kept in separate bottles to avoid inter-species antagonism. The same number of individuals of the rice weevil, *Sitophilus oryzae* (L), the granary weevil, *Sitophilus granarius* (L.) and the lesser grain borer, *Rhyzopertha dominica* (F.) were introduced separately into bottles of the hulled and unhulled teosinte at the three moisture levels. Testing of the Angoumois grain moth, *Sitotroga cerealella* (Oliv.), was accomplished by the introduction of 100 eggs (instead of the adults) to lots of hulled and unhulled grain at the different moisture levels. All insects were introduced into the lots of grain on June 5, 1953, and the grain held in a constant temperature room at 81° F ± 1 and 70 per cent R.H. After a two-week exposure to infestation, the grain in each bottle (except that in which eggs of the Angoumois grain moth had been placed) was screened to remove the adult insects. Care was exercised to return all grain dust to the appropriate bottle to ensure that eggs or larvae of the respective species were not lost as a result of screening the adults out of the grain.

RESULTS.—Adults of the Angoumois grain moth were first noted on July 4, 1

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[3] The teosinte grain was obtained with the assistance of Dr. R. H. Painter from Dr. Irving E. Melhus, former Director of Iowa State College Tropical Research Center, Antigua, Guatemala. Professor D. A. Wilbur provided valuable assistance and suggestions for the conduct of this study.

Table 1.—**Insects used to infest teosinte with 15, 18 and 21 per cent moisture and the approximate number of progeny present at the end of 11 weeks.**[1]

| INSECT | MOISTURE LEVEL (PER CENT) | | | | | |
|---|---|---|---|---|---|---|
| | 15 | | 18 | | 21 | |
| | Hulled | Unhulled | Hulled | Unhulled | Hulled | Unhulled |
| *External Feeders* | | | | | | |
| Flat grain beetles | 1 | — | 1[1] | — | 2[3] | — |
| Saw-toothed grain beetle | 20, and larvae | — | 20[2] | — | 2[3] | — |
| Red flour beetle | 6 dead 2nd instar larvae | — | dead larvae | — | 1[3] | — |
| Confused flour beetle | 9 | — | 0[3] | — | 0[3] | — |
| *Internal Feeders* | | | | | | |
| Rice weevil | 75[2] | 1 dead | 150[2] | 7 dead | 150 many dead[4] | 0 |
| Granary weevil | 1 | 1 dead | 13[2] | 0 | 20[4] | 0 |
| Lesser grain borer | 50 | 1 3 dead | 40 | 1 | 20[3] | 1 dead |
| Angoumois grain moth | 60–70 | 20–30 | 60–70[2] | 20–30 | 60–70[3] | 20–30 |

[1] Up to 20 individuals were counted; figures above that represent estimates of the number of progeny.
[2] Grain slightly moldy.
[3] Grain noticeably moldy.
[4] Grain very moldy and damp.

month after introduction of the eggs, in the unhulled teosinte at the 15 per cent moisture level. Emergence of the moth from the samples of unhulled grain at 17 and 21 per cent moisture level followed on July 6 and 7. Moths did not appear in the hulled grain until July 10, or 35 days following the introduction of the eggs. Adults of the saw-toothed grain beetle began to appear July 9. The emergence dates of the other species were not determined.

All samples of the grain were screened on August 24, nearly 11 weeks after infestation. Table 1 presents the number of progeny as well as the condition of the grain at the time of final screening.

DISCUSSION.—From these data, the red flour beetle appeared least successful in surviving on teosinte. Only one specimen completed larval development to become an adult. The flat grain beetles likewise failed to develop in numbers with teosinte as the source of food. Confused flour beetles produced progeny in grain with 15 per cent moisture but failed to survive in grain at the higher moisture levels probably because of moldiness of the grain. The saw-toothed grain beetle produced numerous progeny but did not survive in moldy grain with 21 per cent moisture. In the various grain samples there were sufficient broken and fractured kernels to provide a suitable size particle for the larval forms of all the external feeders used in the experiment.

Of the internal feeders, the rice weevil appeared to find teosinte most favorable as a host. The granary weevil produced the fewest progeny. There appeared to be a relationship in this insect between the number of offspring and the amount of moisture in the grain, since only one adult emerged in the grain with 15 per cent moisture while increasing numbers appeared in grain at the 18 and 21 per cent moisture levels. This occurred even in the presence of mold. The lesser grain borer emerged in substantial numbers from all samples of hulled grain. The tough seed coat of the unhulled kernels apparently inhibited the development of infestations by the three coleopterous internal feeders. Only two live adults, both lesser grain borers, were found in the samples of unhulled grain exposed to infestation by the rice weevil, granary weevil and lesser grain borer.

The Angoumois grain moth, however, found both the hulled and unhulled teosinte favorable for its development. A second generation had appeared by mid-August. For some reason, the life cycle of the Angoumois grain moth was shorter by 5 to 6 days when reared on unhulled grain than when reared on hulled grain. This may be the result of its habit of webbing

small kernels or kernel fragments into a loose clump and feeding within this cluster of grain. This habit, which has been observed when the Angoumois grain moth was reared from wheat and sorghum, resulted in moths of greater weights with a longer life cycle.

The samples of grain were not destroyed after these data were taken but were set aside in the laboratory. Infestations of saw-toothed grain beetle, lesser grain borer and Angoumois grain moth were still active on December 1, 1953, 6 months after initial infestation. The rice and granary weevil infestations had existed until moldiness of the grain made it unfavorable for them. Some hulled teosinte left in an open container was found to be heavily infested with Indian-meal moth larvae, *Plodia interpunctalla* (Hbn.), at this same time.

SUMMARY.—The grain of teosinte, hulled and unhulled, was exposed to infestation by eight of the more common grain pests. These were flat grain beetle, saw-toothed grain beetle, red flour beetle and confused flour beetle to which only hulled grain was exposed, and the rice weevil, granary weevil, lesser grain borer and Angoumois grain moth, to which both hulled and unhulled teosinte grain was exposed for infestation. Of the external feeders, the red flour beetle was least successful in producing progeny on teosinte whereas the other species varied from a low production of progeny by the flat grain beetles to a substantial number by the saw-toothed grain beetles. All of the internal feeders were able to develop continuous populations on hulled teosinte but only the Angoumois grain moth was able to exist on the unhulled grain. Exposed, hulled grain developed an infestation of Indian meal moth larave, showing that teosinte was also acceptable to this insect as a food.

## LITERATURE CITED

**Melhus, Irving E.**, and Nevin S. Scrinshaw. 1953. Observations on the nutritive value of teosinte. Science **117**(3028): 34–5.

**Reeves, R. G.** 1950. The use of teosinte in the improvement of corn hybrids. Agron. Jour. **42**(5): 248–51.

**Weston, William, H., Jr.** 1929. Observations on tassels of teosinte malformed by *Sclerospora*. Jour. Agr. Res. **39**(11): 817–36.

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# House Fly Control with Diazinon[1]

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House fly control with residual-type sprays of the chlorinated hydrocarbon group has become progressively more difficult in Missouri since 1949. As late as 1951 some early season control of resistant house flies was possible with combinations of lindane with DDT or methoxychlor. However, in 1952, and 1953 applications of any chlorinated hydrocarbon or combinations thereof failed to give any appreciable control. This was true even in local areas where much of the resistance acquired during the summer season had apparently been lost by the following spring.

Hansens & Bartley (1953) have reported on house fly control afforded during the 1952 season in New Jersey by three new insecticides developed by Geigy Co., Inc. Of the three insecticides used by Hansens and Bartley, only Diazinon at 1 per cent controlled house flies satisfactorily. Diazinon in the pure form is a colorless liquid boiling at 83–84° C. under 0.002 mm. Hg. The material is only very slightly soluble in water but dissolves readily in petroleum solvents, acetone, alcohol and xylene.

A small quantity of Diazinon was available for experimentation early in 1953. As nothing was known of the action of the material on the immature forms of the house fly, preliminary laboratory experiments were performed to check the effect of the insecticide on all forms.

LABORATORY TESTS.—*Egg Stage.*—Test cans (1-quart ice cream cartons) containing 150 grams (dry weight) of standard house fly larval medium were used for the tests. The medium was moistened

[1] Missouri College of Agriculture Journal Series No. 1410.

with the usual amount of yeast suspension—Diamalt-water mixture. Diazinon, wettable powder 25 per cent, was added to this moistening mixture at the rate of 5, 25, 50 and 75 mg. (actual insecticide/Kg. of medium). The medium was mixed and allowed to stand in the open air for 24 hours to avoid any initial fumigant effect of the insecticide. Treated test cans and untreated check cans were then seeded with house fly eggs deposited the night before. Three consecutive seedings with eggs were made planting 30 eggs per can the first day, 40 eggs the second day and 20 eggs the third day, or a total of 90 eggs per can in the 3-day period. Five days later the untreated check showed live and rapidly growing larvae. No live larvae were found in any of the cans containing Diazinon-treated medium. Seven days after the first eggs were placed in the test cans pupation took place in the checks. As there were no live larvae in the treated medium 25 additional eggs were placed in each treatment. Fifteen days after the test cans were seeded with eggs normal adult flies emerged from the untreated check cans. Of the 90 eggs placed in the checks 31 per cent hatched and ultimately produced adult flies. No adult flies emerged from any test can containing medium treated with Diazinon.

*Larval Stage.*—To determine the effect small deposits of Diazinon in larval media might have on last instar house fly larvae the following test was made. Last instar fly larvae were placed in quart ice cream cartons containing standard larval medium treated with 1 mg. Diazinon per gram of medium or 1 mg. DDT per gram of medium. Untreated medium served as a check. Results of this experiment are recorded in table 1.

The abnormal puparia formed by 60 per cent of the larvae in the Diazinon-treated medium were characterized by the formation of an incomplete puparium which retained the enlongate form and shape of the larva. None of these abnormal puparia produced adult flies.

**Table 1.—Effect of Diazinon and DDT on last-stage house fly larvae.**

| Treatment | Total No. Larvae | Per Cent Dead | Per Cent Producing | | Per Cent Producing Adults |
|---|---|---|---|---|---|
| | | | Normal Puparia | Abnormal Puparia | |
| Diazinon 1 mg./gm. medium | 48 | 39 | 0 | 60 | 0 |
| DDT 1 mg./gm. medium | 49 | 2 | 98 | 0 | 91 |
| Untreated medium | 41 | 0 | 100 | 0 | 92 |

*Adult Stage.*—Preliminary tests with adult house flies from a known resistant strain which had been overwintered in the laboratory, were conducted early in the spring of 1953. The tests were designed to determine the initial effect of Diazinon residues on this fly strain as field tests in the home area of this strain (University of Missouri Beef Barn) were contemplated during the 1953 season. Concurrent tests with DDT indicated that the high DDT resistance of the strain in 1952 had almost disappeared during the winter of 1952–53. All flies exposed 5 minutes to Diazinon residues of 45, 90 and 188 mg./sq. ft. were affected within 10 minutes and were down within 30 minutes. There was no subsequent recovery. Test flies were exposed in hoop cages according to the method described by Barber & Schmitt (1948).

FIELD TESTS.—The University of Missouri Beef Barn at Columbia was selected as one of the sites for field testing Diazinon because the past spraying history and control difficulties were well known. The barn is approximately 150 feet long and 50 feet wide. It houses beef animals of all ages and types. One wing of the barn opens to the south to feed lots. The roofed portion of this area usually houses 40 to 50 steers on continuous feed programs and is cleaned only once or twice a year. Fly breeding is heavy in this area.

The Beef Barn was sprayed on the morning of May 28, 1953 with 25 per cent Diazinon wettable powder at the rate of 32 pounds per 100 gallons of water. This 1 per cent spray was applied at about 200 pounds pressure and particular attention was paid to spraying vertical resting places such as posts, mangers, entrance ways and windows. The fly population at this time averaged 20 flies per square foot on favored resting places. Kill was complete by 2:00 P.M. on the day of spraying. Five days later an extremely heavy emergence of flies took place in the feed pen area. These flies were all killed within 12 hours by crawling up the treated walls and pen boards of the barn. Excellent control was provided by this spray for 35 days when a gradual build up of flies became apparent. Migration from adjoining barn areas took place continuously

throughout the summer. Practical control was afforded until July 17 (49 days after the spray was applied) when it became necessary to respray the barn. The original spray residue was still killing some flies but emergence and invasion kept the populations too high. The second spray (1 per cent Diazinon) was applied July 17, 1953. This application gave good control of flies for 47 days or until September 3 when fly populations became excessive. The barn was not sprayed again during the 1953 season.

Flies were trapped in the vicinity of this sprayed barn at intervals throughout the summer and exposed to freshly treated glass plates (180 mg. Diazinon/sq. ft.) to see if continuous field exposure to the insecticide was causing resistance to appear in the population. Flies trapped in the barn throughout the summer, and in September after spraying operations were suspended, were as readily killed by Diazinon as were those flies of the inital population. No build up of resistance was evident in the population after 97 days' exposure to Diazinon.

In observing and recording the rise and fall of house fly populations during the test period, it was noted that a substantial kill of stable flies occurred during an 18-day period following the application of the Diazinon sprays. Engorged stable flies leaving the cattle as the animals entered the barn were killed as they rested on sprayed surfaces around the entrance ways. Stable fly populations on the cattle using this barn were substantially reduced during the 18-day period.

Another field test was conducted at the Boonville Bosy Training School Diary at Boonville, Missouri. Diazinon at 1 per cent was applied by means of 3-gallon compressed air sprayers, spraying all walls (up to a height of 8 feet), stanchions, doorways, windows and screens in the stanchion barn, loafing barn, milking parlor and milk-processing room. Care was taken that all feed troughs, watering cups and milk-handling equipment were removed or covered while the spraying was in progress. House flies at this dairy have been highly resistant to all chlorinated hydrocarbon sprays applied since 1949. Excellent control of house flies was afforded by this single application from July 14 to August 19, a period of 36 days. Sanitation practices at this dairy were very good, and local house fly breeding sites were scarce. It is significant that a total of 20 gallons of 1 per cent Diazinon judiciously applied to resting places most favored by house flies afforded 36 days excellent control at this dairy establishment which, is equipped to handle from 70 to 90 milking animals.

Very late in the season a series of cool nights and warm days concentrated a heavy population of house flies in a long open-front beef cattle feeding shed on the campus of the University of Missouri. During the warm parts of the day these flies flooded into adjoining dairy and physiology barns in great numbers. Steers being fed in the shed averaged over 600 flies per head on September 19. A 1 per cent Diazinon spray was applied to all walls, pens and gates in this shed September 19. Cattle and hogs in the pens were simply herded to the far end of the enclosures while spraying was under way. On September 21 house fly populations averaged less than 2 flies per steer in this area. Excellent control continued until late in October when cold weather halted fly activity.

RESIDUE STUDIES.—Observations made during July indicated that the Diazinon residues on doorways, and other entrances exposed to direct sunlight and heat, broke down more rapidly than did residues within the building. A preliminary test to determine the effect of direct sunlight and heat on the residues was set up in August. In this test treated glass plates (180 mg. Diazinon/sq. ft.) were exposed to direct sunlight for 3 hours each day for 16 days. Similarly treated plates were held at room temperature (average daily temperature 83° F.) without direct sunlight. At the end of the 16-day esposure period these plates were exposed to house flies and the knockdown and kill recorded (Table 2).

**Table 2.—Effect of direct sunlight and heat upon residues on glass plates treated with Diazinon, 180 mg./sq. ft.**

| PLATE TREATMENT | PER CENT KNOCKDOWN 30 MINUTES AFTER EXPOSURE[1] | CORRECTED PER CENT KILL 24 HOURS |
|---|---|---|
| Exposed to direct sunlight for 16 days | 0 | 03.3 |
| Held in subdued light | 75 | 78.6 |

[1] House flies exposed to treated surfaces for 3 minutes.

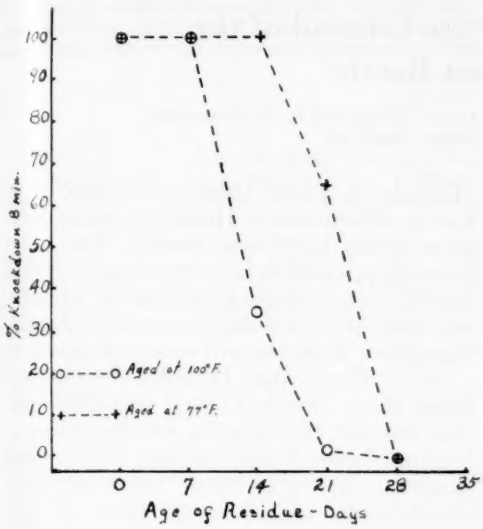


FIG. 1.—Effect of temperature on Diazinon deposits (180 mg./sq. ft. on glass). Knockdown of house flies exposed 3 minutes.

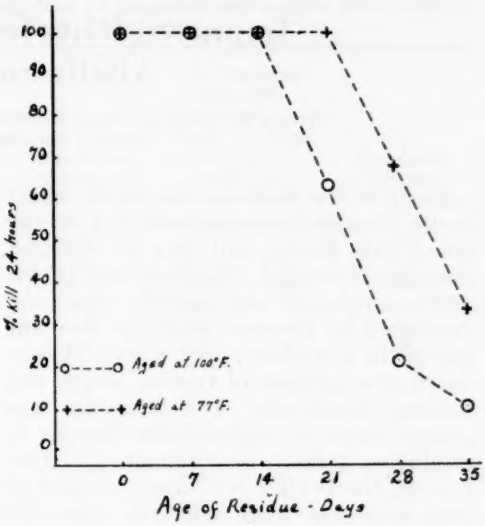


FIG. 2.—Effect of temperature on Diazinon deposits (180 mg./sq. ft. on glass). Mortality of house flies exposed 3 minutes.

Later in the season tests were initiated to determine the effect of heat alone on Diazinon residues. Preliminary tests in which residues were exposed to 140° F. for 30 days indicated that the toxicity of the residues to house flies was reduced by approximately 80 per cent. As field temperatures of 140° F. are never reached in Missouri, other Diazinon-treated plates were held at 100° F. and 77° F. The plates were removed from the temperature holding cabinets at weekly intervals and house flies were exposed to the residues. Results of these experiments are recorded in figures 1 and 2.

SUMMARY.—Preliminary tests with Diazinon against the immature forms of the house fly indicate that as little as 5 mg. of the insecticide per kg. of breeding medium will prevent development of larvae from freshly laid eggs. It was also found that 1 mg. of Diazinon per gram of medium prevented normal pupation of last-instar larvae and emergence of adult flies. Laboratory tests with adult house flies showed that fresh deposits of Diazinon at 45, 90 and 180 mg./sq. ft. knocked down house flies rapidly with no subsequent recovery.

Field tests under conditions of heavy populations and poor sanitation showed that a single application of Diazinon at 1 per cent will control house flies for a period of 35 days. No evidence of resistance to Diazinon was found in a population tested after continuous field exposure to treated surfaces for 97 days.

Data presented indicate that both heat and direct sunlight materially reduce the knockdown effect and subsequent toxicity of Diazinon deposits. This confirms field observations that treated building surfaces exposed directly to the sun during the day may become ineffective sooner than treated surfaces within the building.

## LITERATURE CITED

**Barber, George W.,** and John B. Schmitt, 1948. House flies resistant to DDT residual sprays. N. J. Agr. Expt. Sta. Bul. **742.**

**Hansens, Elton J.,** and C. E. Bartley, 1953. Three new insecticides for house fly control in barns. JOUR. ECON. ENT. **46**(2): 372–3.

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# Improved Baits for the Control of the Alfalfa Snout Beetle[1]

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Early in the work on the alfalfa snout beetle, *Brachyrhinus liguistici* (L.), it was found that poison bait was an effective measure of control. The first bait (Palm 1936) employed successfully was one developed by Downes (1932) for the control of the strawberry root weevil. It consisted of a mixture of raisins, shorts and sodium fluosilicate. This mixture was ground twice through a food chopper to produce a pellet which remained attractive to the beetles for longer periods of time and was more effective than the standard bait of bran, molasses and paris-green or sodium fluosilicate which is still commonly used for grasshoppers and armyworms.

The bait developed by Downes and adopted by Palm remained as the standard control measure for the alfalfa snout beetle from 1936 to 1940 when further work by Lincoln & Palm (1945) indicated that a bait consisting of ground corn cobs, sugar, soybean flour and sodium fluosilicate was nearly as effective as the raisin bait, was easier to prepare, was cheaper and the materials for preparing it were more easily available. Soon after this work, the corn cob bait was adopted. Later peanut hulls were substituted for the ground corn cobs as they were more readily available. A bait, hence forth designated as the standard bait, consisting of peanut shells, 100 pounds; sugar, 20 pounds; soybean flour, 18 pounds; sodium fluosilicate, 8 pounds; formalin, 1 pint and water, 12 gallons was finally adopted and has been used until the present day in the annual control program conducted in the infested area by the New York State Department of Agriculture and Markets.

As early as 1940, it was obvious that the poison bait deteriorated rapidly particularly during periods of adverse weather which are rather common in the infested area during spring. During rainy periods, the baits lost their potency in 2 or 3 days and during very dry periods, the bait would dry out and became unattractive to the beetles in a similar period. Various stickers and conditioners were employed (Lincoln & Palm 1940) to correct this loss in effectiveness. However, these only gave rather indifferent results. The only answer appeared to be a retreatment of the baited area, following periods of adverse weather, at 3 to 5 day intervals if beetle emergence from the soil was prolonged.

After World War II, with the cost of labor at an all time high, it was apparent that the cost of retreating was becoming a limiting factor in maintaining the baiting program. It was obvious that a material which would persist longer than sodium fluosilicate was needed even though sodium fluosilicate was safe, cheap and effective. Therefore in 1950, a study was initiated on the use of chlorinated hydrocarbon insecticides as substitutes for sodium fluosilicate in the standard bait. Since most chlorinated hydrocarbon insecticides are nearly insoluble in water, have contact action and a long residual toxicity, they would seem ideal for the baiting program on the alfalfa snout beetle where long periods of effectiveness are necessary as beetle emergence from the soil is usually prolonged.

Studies with baits during 1950 were limited to two preliminary field trials in which aldrin, dieldrin and chlordane were substituted for sodium fluosilicate at the rate of 1 and 2 pounds for each 8 pounds of sodium fluosilicate. After the toxicants were weighted out, they were mixed in 3 bushel lots in the usual manner by the staff employed for mixing the standard bait for the New York State Department of Agriculture and Markets.

In Experiment A, the baits were applied immediately after mixing on the afternoon of May 6, 1950. During the evening a light shower fell in the area of the baited plots. In Experiment B, the baits were mixed, a preservative, formalin, was added and

[1] The authors are indebted to C. M. Edmonds of the New York State Department of Agriculture and Markets who supervised the mixing and spreading of the baits in the field plots and to Dr. D. S. Marshall, now with California Spray-Chemical Corporation, and to W. G. Evans who participated in some of the work reported here.

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[3] Now located at the Dominion Entomological Laboratory, Saskatoon, Sask.

Table 1.—**Effectiveness of aldrin, dieldrin, and chlordane as compared with sodium fluosilicate in the standard alfalfa snout beetle bait. Belleville, New York. May, 1950.**

| Insecticide | Act. Tox. Lbs./A. | No. Beetles per 100 | | Per Cent Control | No. Beetles per 100 | | Per Cent Control |
|---|---|---|---|---|---|---|---|
| | | Dead | Alive | | Dead | Alive | |
| | | 12 Hours | | | 48 Hours | | |
| | | | | *Test A—without formalin*[1] | | | |
| Aldrin | 1.0 | 84 | 16 | 84 | 100 | 0 | 100 |
| Aldrin | 2.0 | 84 | 16 | 84 | 100 | 0 | 100 |
| Dieldrin | 1.0 | 76 | 24 | 76 | 98 | 2 | 98 |
| Dieldrin | 2.0 | 95 | 5 | 95 | 100 | 0 | 100 |
| Chlordane | 1.0 | 76 | 24 | 76 | 96 | 4 | 96 |
| Chlordane | 2.0 | 82 | 18 | 82 | 98 | 2 | 98 |
| Standard Bait: Sodium fluosilicate | 8.0 | 73 | 27 | 73 | 97 | 3 | 97 |
| | | | | *Test B—with formalin*[2] | | | |
| Aldrin | 1.0 | 50 | 50 | 50 | 97 | 3 | 97 |
| Aldrin | 2.0 | 61 | 39 | 61 | 100 | 0 | 100 |
| Dieldrin | 1.0 | 71 | 29 | 71 | 99 | 1 | 99 |
| Dieldrin | 2.0 | 72 | 28 | 72 | 99 | 1 | 99 |
| Chlordane | 1.0 | 45 | 55 | 45 | 96 | 4 | 96 |
| Chlordane | 2.0 | 49 | 41 | 49 | 97 | 3 | 97 |
| Standard Alfalfa Snout Beetle Bait: Sodium fluosilicate | 8.0 | 40 | 60 | 40 | 88 | 12 | 88 |

[1] Applied May 6, 1950.
[2] Applied May 13, 1950.

they were allowed to stand for 1 week before applying to determine the effects of storage on the toxicity of the baits. All of the baits were applied at the rate of 3 bushels per acre to acre-size plots of alfalfa sod which had been plowed in the fall of 1949.

Effectiveness of the baits was determined by counting 25 beetles in each of 4 quadrants of the acre-size, rectangular plots and recording these as dead or alive. Counts were made at 12 and 48 hour intervals after treatment. These results are presented in table 1. Since the smaller dosage of each insecticide was highly effective in 1950, the dosages were reduced in the tests in 1951 but infestations of alfalfa snout beetle were too small to evaluate the toxicity of these smaller dosages. Therefore, these data are not reported here.

In 1952, a rather extensive series of field and laboratory tests was conducted using aldrin, dieldrin, chlordane, heptachlor, isodrin and endrin baits at the rates of 1.0, 0.5, 0.25 and 0.125 pound of actual toxicant per acre. The field tests were applied on two farms in the Belleville area on April 22 and 23, 1952. Effectiveness of the baits was again jugded by counts of beetles at 48 hours and at 1 week in the manner previously described. Unfortunately the infestation of beetles was so irregular that in many of the plots 100 beetles could not be found. Hence all of the beetles that could be found by three men in a search of each plot for 20 minutes was recorded. The results from the two experiments were averaged together and are presented in table 2.

Since the field infestations of beetles were so uneven, it was obvious that field results would have to be supplemented with laboratory tests. Beetles were collected by hand and were placed together with a fresh supply of alfalfa leaves in a large cage measuring 2 ft. ×3 ft.×1 ft. The food was replaced daily until the beetles were used.

A 500 gram sample of bait was taken from each lot of bait mixed for the field tests and brought back to the laboratory. Part of the this sample was allowed to dry for 1 week and part was placed in boxes outside to weather in the rain and sun for 1 month. Drying and weathering are particularly harmful to the effectiveness of the standard bait. Two grams of each bait from samples of each method of physical treatment were placed in pint-size, ice-cream containers. Each treatment was replicated 4 times and 25 beetles were placed in each carton. The untreated car-

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**Table 2.—Control of the alfalfa snout beetle substituting different chlorinated hydrocarbon insecticides for sodium fluosilicate in the standard bait. Belleville, New York. April, 1952.**

| Insecticide | Act. Tox. Ozs./A. | No. Beetles | | Per Cent Control | No. Beetles | | Per Cent Control |
|---|---|---|---|---|---|---|---|
| | | Dead | Alive | | Dead | Alive | |
| | | 48 Hours | | | 1 Week | | |
| Aldrin | 16[1] | 25 | 19 | 56 | 11 | 2 | 84 |
| | 8 | 48 | 2 | 96 | 80 | 0 | 100 |
| | 4[1] | 5 | 0 | 100 | 7 | 0 | 100 |
| | 2[1] | 136 | 14 | 90 | 154 | 0 | 100 |
| Dieldrin | 16 | 48 | 2 | 96 | 74 | 0 | 100 |
| | 8 | 49 | 1 | 98 | 60 | 0 | 100 |
| | 4 | 5 | 0 | 100 | 11 | 0 | 100 |
| | 2 | 25 | 0 | 100 | 16 | 1 | 94 |
| Chlordane | 16[1] | 50 | 0 | 100 | 70 | 0 | 100 |
| | 8[1] | 128 | 4 | 96 | 24 | 1 | 96 |
| | 4[1] | 96 | 7 | 93 | 30 | 4 | 88 |
| | 2 | 48 | 2 | 96 | 28 | 2 | 93 |
| Heptachlor | 16 | 50 | 0 | 100 | 58 | 2 | 96 |
| | 8[1] | 100 | 8 | 92 | 52 | 2 | 96 |
| | 4 | 50 | 0 | 100 | 68 | 0 | 100 |
| | 2[1] | 106 | 5 | 95 | 105 | 3 | 97 |
| Isodrin | 16 | 48 | 2 | 96 | 83 | 1 | 98 |
| | 8 | 0 | 0 | — | 8 | 0 | 100 |
| | 4 | 50 | 0 | 100 | 60 | 0 | 100 |
| | 2 | 45 | 5 | 90 | 78 | 0 | 100 |
| Endrin | 16 | 48 | 2 | 96 | 60 | 0 | 100 |
| | 8 | 48 | 2 | 96 | 86 | 6 | 93 |
| | 4 | 0 | 0 | — | 1 | 0 | — |
| | 2 | 46 | 4 | 92 | 38 | 2 | 95 |

[1] Average of two experiments.

tons designated as checks contained beetles which were given fresh alfalfa leaves daily. The beetles were examined at 48 hours, 1 week and 2 weeks after treatment for effectiveness of the insecticides. These data are recorded in tables 3 and 4.

In 1953, another series of plots each of which was 1 acre in size was laid out in alfalfa sod which had been plowed in the fall of 1952. Aldrin, dieldrin, heptachlor and isodrin were applied as baits at the rates of 1, 2 and 4 ounces of actual toxicant per acre. All of the materials were applied at at least two locations. Isodrin at 2 ounces per acre was applied to areas covering 20 acres in a practical demonstration of control. Effectiveness was judged in a manner described previously at intervals ranging from 1 day to 1 week (whenever it was possible to work between showers). These results are presented in table 5.

Discussion.—In field tests in 1950, aldrin, dieldrin and chlordane at dosages of 1 and 2 pounds per acre gave excellent control of the alfalfa snout beetle which was equal to or better than the control obtained from the use of the standard bait. There was little to choose between the organic insecticides at these dosages. One pound was about as effective as 2 pounds, particularly at the 48 hour count. Storage of the mixed bait for a week did not seem to decrease its attractiveness to the beetles nor markedly affect its toxicity, particularly at the 48 hour count.

To determine the lower limit of effectiveness of aldrin, dieldrin and chlordane a series of concentations ranging from 0.125 to 1 pound of these and other materials were tested in the field in 1952. It was found that even the lowest dosage gave excellent control of the alfalfa snout beetle in the field and that there was little to choose between any of the organic insecticides. One peculiar feature in the use of the organic baits was its ability to immobilize the beetle rapidly, but the insect continued to live in a helpless moribund

Table 3.—Control of the alfalfa snout beetle in cage tests substituting chlorinated hydrocarbon insecticides for sodium fluosilicate in the standard bait. Minetto, New York. April 29, 1952.

| Insecticide[1] | Act. Tox. Ozs./A. | No. Beetles per 100 | | Per Cent Control | No. Beetles per 100 | | Per Cent Control |
|---|---|---|---|---|---|---|---|
| | | Dead | Alive | | Dead | Alive | |
| | | 48 Hours | | | 1 Week | | |
| Aldrin | 16 | 87 | 13 | 87 | 100 | 0 | 100 |
| | 8 | 77 | 23 | 77 | 100 | 0 | 100 |
| | 4 | 87 | 13 | 87 | 100 | 0 | 100 |
| | 2 | 16 | 84 | 16 | 100 | 0 | 100 |
| Dieldrin | 16 | 93 | 7 | 93 | 100 | 0 | 100 |
| | 8 | 82 | 18 | 82 | 100 | 0 | 100 |
| | 4 | 24 | 76 | 24 | 100 | 0 | 100 |
| | 2 | 5 | 95 | 5 | 100 | 0 | 100 |
| Chlordane | 16 | 69 | 31 | 69 | 100 | 0 | 100 |
| | 8 | 68 | 32 | 68 | 100 | 0 | 100 |
| | 4 | 5 | 95 | 5 | 100 | 0 | 100 |
| | 2 | 2 | 98 | 2 | 94 | 6 | 49 |
| Heptachlor | 16 | 99 | 1 | 99 | 100 | 0 | 100 |
| | 8 | 99 | 1 | 99 | 100 | 0 | 100 |
| | 4 | 96 | 4 | 96 | 100 | 0 | 100 |
| | 2 | 91 | 9 | 91 | 100 | 0 | 100 |
| Isodrin | 16 | 72 | 28 | 72 | 100 | 0 | 100 |
| | 8 | 50 | 50 | 50 | 100 | 0 | 100 |
| | 4 | 2 | 98 | 2 | 100 | 0 | 100 |
| | 2 | 0 | 100 | 0 | 100 | 0 | 100 |
| Untreated check | — | 0 | 100 | — | 0 | 100 | — |

[1] All baits dried 1 week before using.

state for days. In several of the experiments, moribund beetles were collected, counted and placed in well-marked locations. Periodically for a fortnight, the beetles were reexamined and counted. In no cases did any of the affected beetles recover although some remained in a moribund condition for over 1 week before dying.

In the cage tests it was found that unlike the inorganic baits drying, or periodic wetting and drying, did not destroy the effectiveness of the various organic insecticide baits although such treatments apparently did reduce the speed of kill with the lower concentrations of some insecticides (See Table 3). Of all the baits tested, heptachlor bait appeared to maintain its effectiveness best under adverse conditions.

In large-scale demonstration plots treated in 1953, it was found that even 1 ounce per acre, of the insecticides tried at that concentation, (dieldrin, heptachlor and isodrin) was highly effective. Isodrin was applied to 20 acres of plowed sod where it gave excellent control of the alfalfa snout beetle for over 1 month during which time it continued to kill each new group of freshly emerging beetles. From these tests, it would appear that even less than 1 ounce per acre of some of the chlorinated hydrocarbon insecticides incorporated in the standard bait would give practical control.

SUMMARY.—In a series of experiments conducted from 1950 to 1953, it was found that 1 and 2 ounces of aldrin, dieldrin, chlordane, heptachlor, isodrin and endrin substituted for sodium fluosilicate in the standard bait gave good control of the alfalfa snout beetle and persisted in their effectiveness for periods of 1 month or more. No retreatment of the baited area was necessary where such baits were employed.

Storage of mixed bait, drying, or periodic wetting and drying did not reduce the overall effectivenesss of these baits containing chlorinated hydrocarbon insecticides although the speed of kill seemed to be retarded in some instances.

Since even 1 ounce per acre of some of the insecticides tested gave good control

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**Table 4.—Control of the alfalfa snout beetle in cage tests substituting chlorinated hydrocarbon insecticides for sodium fluosilicate in the standard bait. Minetto, New York. May 20, 1952.**

| Insecticide[1] | Act. Tox. Ozs./A. | No. Beetles per 100 | | Per Cent Control | No. Beetles per 100 | | Per Cent Control |
|---|---|---|---|---|---|---|---|
| | | Dead | Alive | | Dead | Alive | |
| | | 48 Hours | | | 1 Week | | |
| Aldrin | 16 | 77 | 23 | 77 | 100 | 0 | 100 |
| | 8 | 65 | 35 | 64 | 100 | 0 | 100 |
| | 4 | 41 | 59 | 41 | 100 | 0 | 100 |
| | 2 | 53 | 47 | 53 | 100 | 0 | 100 |
| Dieldrin | 16 | 95 | 5 | 95 | 100 | 0 | 100 |
| | 8 | 98 | 2 | 98 | 100 | 0 | 100 |
| | 4 | 95 | 5 | 95 | 100 | 0 | 100 |
| | 2 | 96 | 4 | 96 | 100 | 0 | 100 |
| Chlordane | 16 | 93 | 7 | 93 | 100 | 0 | 100 |
| | 8 | 91 | 9 | 91 | 100 | 0 | 100 |
| | 4 | 67 | 33 | 67 | 100 | 0 | 100 |
| | 2 | 88 | 12 | 88 | 100 | 0 | 100 |
| Heptachlor | 16 | 99 | 1 | 99 | 100 | 0 | 100 |
| | 8 | 92 | 8 | 92 | 100 | 0 | 100 |
| | 4 | 93 | 7 | 93 | 100 | 0 | 100 |
| | 2 | 92 | 8 | 92 | 100 | 0 | 100 |
| Untreated check | — | 0 | 100 | — | 0 | 100 | — |
| | | *1 week* | | | *2 weeks* | | |
| Isodrin | 16 | 100 | 0 | 100 | 100 | 0 | 100 |
| | 8 | 100 | 0 | 100 | 100 | 0 | 100 |
| | 4 | 100 | 0 | 100 | 100 | 0 | 100 |
| | 2 | 100 | 0 | 100 | 100 | 0 | 100 |
| Endrin | 16 | 100 | 0 | 100 | 100 | 0 | 100 |
| | 8 | 100 | 0 | 100 | 100 | 0 | 100 |
| | 4 | 98 | 2 | 98 | 100 | 0 | 100 |
| | 2 | 94 | 6 | 94 | 100 | 0 | 100 |
| Untreated check | — | 0 | 100 | — | 0 | 100 | — |

[1] All baits weathered in sun and rain for 1 month before application.

of the alfalfa snout beetle, it would appear that even smaller dosages of these materials would be effective.

Beetles were affected quickly by the chlorinated hydrocarbon insecticides but did not die immediately. They remained in a moribund state for periods as long as 1 week. In no cases, did any of the affected beetles which were examined recover.

**Table 5.—Control of the alfalfa snout beetle in field experiments substituting chlorinated hydrocarbon insecticides for sodium fluosilicate in the standard bait. Belleville, New York. 1953.**

| | Act. Tox. Ozs./A. | No. Locations | Date Applied | Date Counts Made | No. Beetles | | Per Cent Control |
|---|---|---|---|---|---|---|---|
| | | | | | Dead | Alive | |
| Aldrin | 4 | 2 | 5/5 | 5/11 | 12 | 0 | 100 |
| Dieldrin | 4 | 2 | 5/5 | 5/11 | 100 | 0 | 100 |
| | 2 | 2 | 5/5 | 5/11 | 100 | 0 | 100 |
| | 1 | 2 | 5/4 | 5/5 | 97 | 0 | 100 |
| Heptachlor | 4 | 2 | 5/11 | 5/18 | 20 | 0 | 100 |
| | 2 | 2 | 5/11 | 5/18 | 15 | 2 | 88 |
| | 1 | 2 | 5/11 | 5/18 | 5 | 1 | 83 |
| Isodrin | 2 | 20 | 5/4 | 5/5 | 787 | 13 | 98 |
| | 1 | 4 | 5/11 | 5/18 | 36 | 0 | 100 |

LITERATURE CITED

Downes, W. 1932. The strawberry root weevil with notes on other insects affecting strawberries. Canada Dept. Agr. Pamph. *n.s.* 5: 1–9.

Lincoln, C. G., and C. E. Palm. 1940. New baits for the control of the alfalfa snout beetle, *Brachyrhinus ligustici* (L.) JOUR. ECON. ENT. 33(4): 639–43.

Palm, C. E. Status of the alfalfa snout beetle in New York. JOUR. ECON. ENT. 29: 960–5.

# Distribution of the European Corn Borer Parasite *Perezia pyraustae*, and Its Effect on the Host[1]

H. L. ZIMMACK,[2,3] K. D. ARBUTHNOT,[2] and T. A. BRINDLEY[2,3]

The finding of *Perezia pyraustae* Paillot[4] in the United States was reported by Steinhaus (1951, 1952), and the results of studies on the organism have been published by Hall (1952). Early in 1952 difficulties were encountered at the laboratory of the Bureau of Entomology and Plant Quarantine at Ankeny, Iowa, when hibernating larvae of the European corn borer, *Pyrausta nubilalis* (Hbn.), were incubated to provide eggs for insecticide tests. The mortality of the borers was unusually high, and the moths obtained from them did not lay the expected number of eggs. Dead borers were sent to Dr. Steinhaus, who found most of them to be infected with *Perezia*. Moths that failed to begin laying within the normal time (3 to 5 days after emergence) were killed and forwarded to Dr. Steinhaus, who found them infected also.

These findings indicated that the microsporidian was causing death of the larvae and the failure of moths to lay. It was evident that a study of this parasite should be undertaken where the corn borer was present, and this could not be done in California (Hall 1952). Accordingly studies were initiated in Iowa; the facilities of Iowa State College at Ames were used, especially in the field of protozoology,[5] and those at Ankeny for most of the entomological phases. Observations that have been made on the distribution of *Perezia* and its effect on the European corn borer are summarized in this paper.

DISTRIBUTION.—Preliminary observations on living borers from several Iowa counties showed that many of them were infected by *Perezia pyraustae*. Entomologists in the North Central States were invited to send overwintered borers for diagnosis to the laboratory so that its distribution in the region might be determined. Samples were received from 80 counties in seven States.[6] As shown in table 1, *Perezia* was found in the collections from 68 counties, including all seven States.

**Table 1.—A summary of *Perezia pyraustae* findings on hibernated European corn borers collected in seven North Central States in the spring of 1952.**

| STATE | NUMBER OF COUNTIES | | NUMBER OF SAMPLES | | TOTAL NUMBER OF BORERS EXAMINED |
|---|---|---|---|---|---|
| | Sampled | Infected | Examined | Infected | |
| Illinois | 12 | 10 | 15 | 12 | 141 |
| Iowa | 20 | 16 | 77 | 55 | 953 |
| Michigan | 2 | 2 | 2 | 2 | 12 |
| Minnesota | 27 | 23 | 69 | 60 | 772 |
| Ohio | 3 | 3 | 4 | 4 | 70 |
| South Dakota | 11 | 9 | 16 | 14 | 126 |
| Wisconsin | 5 | 5 | 5 | 5 | 29 |
| Total | 80 | 68 | 188 | 152 | 2,103 |

In additional collections made in 47 Iowa counties during the development of the summer brood, *Perezia*-infected borers were found from 28 counties. Of 56 samples, containing 375 borers, that were examined, 33 samples contained infected borers. The counties in which *Perezia pyraustae* was found in 1952 are listed below.

[1] The data in this paper are taken largely from a thesis submitted by H. L. Zimmack in partial fulfillment of the requirements for the degree of master of science in entomology, Iowa State College. Journal Paper No. J-2206 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1193.

[2] Entomology Research Branch Agr. Res. Serv., U.S.D.A.

[3] Iowa State College.

[4] Tentative classification based on the findings of Hall (1952).

[5] The authors express their appreciation to E. R. Becker, protozoologist at Iowa State College, for his interest and assistance in many phases of this study.

[6] Entomologists and the agencies in the States that provided samples were as follows: George C. Decker, Natural History Survey, Illinois; H. M. Harris, Department of Zoology and Entomology, Iowa State College; Ray L. Janes, Department of Entomology, Michigan State College; A. W. Buzicky, Minnesota State Department of Agriculture, and F. W. Holdaway, Agricultural Experiment Station, University of Minnesota; Edwin T. Hibbs, Agricultural Experiment Station, Ohio State University; Gerald B. Spawn, Agricultural Experiment Station, South Dakota State College; and E. H. Fisher, Agricultural Extension Service, University of Wisconsin.

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LOCATION OF SPORES IN THE HOST.—*Perezia* spores were found in all stages of the host. In larvae the lumen of the Malpighian tubules was sometimes filled and even greatly distended with spores, and infected tubules had an opaque white appearance, contrasting sharply with their normal yellow color. Spores were often found in the lumen of the salivary and silk glands and occasionally in the hind gut near the origin of the Malpighian tubules. They were found more often in the cells than in the lumen. In heavily infected organs the spores were often released into the lumen, apparently from ruptured host cells. The lumen of heavily infected Malpighian tubules sometimes contained floating compact sporelike masses, encased in a membranous structure.

Infection in the pupae was difficult to determine because the tissues were often disorganized in metamorphosis. However, spores were found in the Malpighian tubules and in the silk and salivary glands.

In the moths spores were present in the Malpighian tubules and the reproductive organs of both sexes. The bursa copulatrix was often filled with them. Since unlaid eggs dissected from moths, unhatched eggs, and newly hatched larvae of *Perezia*-infected insects all contained spores, it was concluded that transmission is accomplished through the eggs.

External metabolic products from isolated infected borers were examined to determine whether diagnosis could be made from them. Spores were present in each of 34 frass samples. They were also found in 12 of 19 samples of silk spun by growing larvae. It is not surprising that some of the silk samples did not contain spores, since all larvae did not show infestation in the silk glands. Spores were found in 4 of 7 molted head capsules.

EFFECT ON THE HOST.—In May copulating moths were captured in a large cage at Ankeny where corn borer-infested stalks from Lyon County were stored to provide moths for resistance studies on the pest. Each captured pair was caged in the laboratory for egg laying. The egg masses and the moths after their death were examined for *Perezia*. A total of 116 moths (75 females and 41 males) and 811 egg masses were examined.

LONGEVITY AND EGG LAYING.—Data on 59 pairs pertinent to longevity of the female moths and to egg production are summarized in table 2. The *Perezia*-infected moths averaged more than 4 days shorter life, 7 fewer egg masses, and less than half as many eggs as the uninfected moths. More than half of their egg masses showed infection, and they laid some infertile eggs, in contrast to none from the uninfected moths. An egg was diagnosed as infertile if no embryological development could be observed while the remaining eggs in the mass showed signs of such development. It was not determined whether the infertility was due to *Perezia*, lack of fertilization, or other causes.

The production of the eight moths that laid only uninfected eggs was even lower than that of the 44 moths that laid infected masses. There was no evidence that spores in the male contributed to egg infection in the female, since six of the uninfected females that produced egg masses free from spores had mated with infected males.

Four mated female moths were captured in a stalk cage at Toledo, Ohio, for study at Ankeny. None of them harbored *Perezia*, and all their eggs were uninfected. They averaged 11.5 days of life,

Table 2.—Effect of *Perezia pyraustae* on longevity and egg production of European corn borer moths collected in Lyon County, Iowa.

| Group of Moths | Number of Moths | Days from Mating to Death | | Number of Egg Masses | | | | Number of Eggs Produced | | Number of Infertile Eggs | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Produced | | Infected | | | | | |
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Infected moths that laid— | | | | | | | | | | | |
| Infected eggs | 44 | 3–17 | 9.5 | 1–37 | 13.6 | 1–33 | 9.8 | 5–751 | 204.9 | 0–64 | 5.7 |
| Uninfected eggs | 8 | 5–17 | 10.8 | 2–22 | 8.9 | 0 | 0 | 6–277 | 93.8 | 0–6 | 0.8 |
| Uninfected moths that laid eggs, all uninfected | 7 | 10–17 | 14 | 4–38 | 21.3 | 0 | 0 | 73–844 | 394.7 | 0 | 0 |

46.5 egg masses, and 607.5 eggs, of which 7.8 were infertile.

LABORATORY TESTS WITH REARED STOCK.—In August breeding stock was obtained by collecting summer-brood larvae and pupae from Lyon and Polk Counties, Iowa, for laboratory testing of *Perezia* on other stages of the host. Seven egg-laying females were used, and their eggs were kept at 50° F. to retard embryonic development until the moths died and could be examined. Five of these females were *Perezia*-infected. Laboratory rearings were made with eggs from two each of the infected and uninfected moths. Except where otherwise indicated, all rearing was done at a constant temperature of 80° and a relative humidity of 70 per cent or above. Eggs were incubated in a saturated atmosphere until they reached the blackhead stage. They were then placed on food in ¾- by 1-inch shell vials for hatching, and here the larvae were confined for 5 to 10 days by a covering of fine-mesh linen cloth attached in a wax ring about the mouth of the vial. At the end of this time they were isolated in ½- by 2-inch shell vials with copper screw caps supplemented by a cloth gasket until they reached the fifth instar. The larval growth rates, as shown by the numbers in each instar, and survivials are summarized in table 3. It is noteworthy that 98 per cent of the eggs from the uninfected moths and 87 per cent from the infected moths hatched.

The growth rates were about the same at 5 days, but survival was more than 20 per cent higher in the uninfected than in the infected group. Differences in survival were even greater at 19 and 31 days, when striking differences were also found in the growth rates. No fifth-instar larvae were found in the infected group after 19 days, whereas 59 per cent in the uninfected group had reached this stage. All the uninfected survivors had reached the fifth instar and 73 per cent had pupated in 31 days, but in the infected group more than half had not reached the fifth instar and none had pupated. No larvae in the uninfected group died between 31 and 45 days, and pupation reached 90 per cent. No pupa was reared in the diseased group, and all larvae died within 60 days.

During these rearings dead borers were frequently examined for *Perezia*. None were found in those from uninfected moths, but spores were always present in dead borers from the infected moths.

Uninfected moths reared in the preceding experiment were used to provide eggs for laboratory tests to induce infestations. In one test a mass of 49 eggs was dipped into distilled water (check) and another of 47 eggs was dipped into a suspension of *Perezia* spores just before the eggs were placed in vials for rearing. Four days after hatching larval survival was 76 per cent (6 first and 31 second instars) in the check and 19 per cent (4 first and 5 second instars) in the treated group. En masse examination of the dead larvae showed infection in the treated group but none in the check.

In another test with eggs from uninfected moths, the food (sections of green corn plants) was smeared with a suspension of *Perezia* spores in the treated lot and with distilled water in the check. Excessive moisture caused the development of fungi in both lots, and rearings were not completed, but recovered dead larvae from the treated lot showed infection whereas none was found in the check.

Rearings to maintain a stock of *Perezia*-free borers for laboratory tests were started with additional eggs from the moths in the earliest rearings. Three masses with a total of 60 eggs were in one

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**Table 3.—Survival of European corn borers reared in the laboratory from two *Perezia*-infected and two uninfected moths.**

| Progeny | From Uninfected Moths | From Infected Moths |
|---|---|---|
| Fertile eggs: | | |
| Laid | 313 | 256 |
| Hatched | 307 | 223 |
| Surviving larvae and pupae: | | |
| 5 days after hatching | | |
| First instar | 35 | 9 |
| Second instar | 234 | 125 |
| Third instar | 0 | 8 |
| Per cent survival | 87.6 | 63.7 |
| 19 days after hatching | | |
| Third instar | 8 | 13 |
| Fourth instar | 52 | 19 |
| Fifth instar | 84 | 0 |
| Pupae | 2 | 0 |
| Per cent survival | 47.6 | 14.3 |
| 31 days after hatching | | |
| Third instar | 0 | 1 |
| Fourth instar | 0 | 14 |
| Fifth instar | 34 | 11 |
| Pupae | 93 | 0 |
| Per cent survival | 41.3 | 11.7 |

**Table 4.—Survival of European corn borer larvae in uninfected stock and in stock in which *Perezia* infection was induced.**

| Larvae | From Uninfected Moths | From Infected Moths |
|---|---|---|
| Started | 140 | 92 |
| Surviving 4 days: | | |
| First instar | 30 | 28 |
| Second instar | 73 | 12 |
| Per cent survival | 73.6 | 43.5 |
| Surviving 7 days: | | |
| First instar | 1 | 1 |
| Second instar | 35 | 8 |
| Third instar | 32 | 0 |
| Per cent survival | 48.6 | 9.8 |
| Surviving 10 days: | | |
| Second instar | 2 | 0 |
| Third instar | 32 | 3 |
| Fourth instar | 14 | 0 |
| Per cent survival | 34.3 | 3.3 |
| Surviving 14 days: | | |
| Second instar | 1 | 0 |
| Third instar | 15 | 2 |
| Fourth instar | 22 | 0 |
| Fifth instar | 7 | 0 |
| Per cent survival | 32.1 | 2.2 |

group, and two masses with 65 eggs were in another group. Four days after hatching the remnants of the egg masses were examined. One mass in the first group was found to be infected, and in this group, in which 45 eggs hatched, survival was only 13 per cent after 7 days. Survival in the second group, in which 64 eggs hatched, was 36 per cent after 7 days.

In another rearing 27 first-instar larvae were started to maintain an uninfected stock of borers. The numbers surviving from this group and from the uninfected group previously discussed were combined for comparison with the combined survival data from an infected group obtained by dipping an egg mass in a spore suspension and the previous group that showed one egg mass infected. Table 4 shows that the rate of growth was much slower in the infected group.

Tests to Induce Borer Infection in the Field.—Eighty-eight random fields in Boone County were sampled for summer-brood borers. Of 39 borers taken in 22 fields which were examined for *Perezia*, only 2, a third-instar larva and a pupa, were infected. This low incidence provided the possibility of testing methods of inducing or increasing the infection in borers in the field, and thereby affecting borer populations. Two preliminary tests were made in one of these fields that was receiving a heavy egg load.

In the first test 10 paired hills in two rows, separated by two buffer rows and with two buffer hills between them in the rows, were selected on August 12. On every other hill approximately 390 ml. of a *Perezia* spore suspension was applied with a household sprayer. This suspension had an average of 7.05 spores in a microscope field 0.106 mm. in diameter, or approximately 1,556,000 spores per milliliter as estimated with a Levy blood-counting chamber.

In the second test 40 hills showing hatched or unhatched egg masses on the plants were selected on August 16. On August 18 half of these hills were sprayed with approximately 600 ml. of a suspension that had an average of 5.83 spores in a field 0.106 mm. in diameter, or approximately 1,286,000 spores per milliliter as estimated with the Levy blood-counting chamber.

All the plants in the first test and the plants in 22 hills in the second test were dissected on September 17 and 18, and borers were examined for *Perezia*. In the first test no infection was found in any of the borers from the untreated hills, but 37.5 per cent of the borers in the treated

Table 5.—Results of two field tests in which half the hills were sprayed with a suspension of Perezia spores.

| Borers in Untreated Hills | | Borers in Treated Hills | |
|---|---|---|---|
| Total Number | Number Infected | Total Number | Number Infected |
| *Tests with paired hills*[1] | | | |
| 3 | 0 | 16 | 6 |
| 8 | 0 | 2 | 2 |
| 4 | 0 | 4 | 1 |
| 0 | — | 7 | 3 |
| 3 | 0 | 3 | 0 |
| 1 | 0 | 6 | 3 |
| 6 | 0 | 8 | 1 |
| 3 | 0 | 1 | 1 |
| 3 | 0 | 1 | 1 |
| 1 | 0 | 0 | — |
| Per cent survival | 0 | — | 37.5 |
| *Tests with hills having egg masses when treated* | | | |
| 19 | 6 | 16 | 13 |
| 7 | 0 | 3 | 1 |
| 11 | 0 | 12 | 6 |
| 17 | 0 | 18 | 12 |
| 14 | 2 | 30 | 8 |
| 11 | 1 | 14 | 6 |
| 23 | 3 | 6 | 2 |
| 14 | 6 | 24 | 3 |
| 28 | 18 | 5 | 1 |
| 24 | 0 | 21 | 2 |
| 17 | 5 | 22 | 8 |
| Per cent survival | 22.2 | — | 36.2 |

[1] Plants in paired hills may or may not have had egg masses present.

hills were infected. In the second test infected larvae were found in seven of the untreated and all of the treated hills. Data on borers from the 42 hills are given in table 5.

SUMMARY AND CONCLUSIONS.—The microsporidian, *Perezia pyraustae* Paillot, was found infecting the European corn borer, *Pyrausta nubilalis* (Hbn.), in 90 counties in 7 North Central States distributed as follows: Illinois 10, Iowa 38, Michigan 2, Minnesota 23, Ohio 3, South Dakota 9, and Wisconsin 5.

In studies on this parasite in Iowa uninfected female moths laid only *Perezia*-free eggs whether or not their mates were infected. Diseased moths usually laid infected eggs, and they were shorter lived and laid fewer eggs than the uninfected moths. It was therefore concluded that *Perezia* is transmitted through the egg.

Infection was induced in the laboratory when unhatched eggs were dipped in a spore suspension and when spores were smeared on the food.

Larval survival was lower and growth was slower in infected than in uninfected borers, whether they came from diseased moths or had the disease induced. No pupae were reared from diseased borers in the laboratory.

A preliminary field test showed higher percentages of diseased borers in hills of corn treated with spores than in untreated ones, but the results were not conclusive.

## LITERATURE CITED

Hall, Irvin M. 1952. Observations on *Perezia pyraustae* Paillot, a microsporidian parasite of the European corn borer. Jour. Paraistol. **38:** 48–62.

Steinhaus, Edward A. 1951. Report on diagnoses of diseased insects 1944–1950. Hilgardia **20:** 629–78.

Steinhaus, Edward A. 1952. Microbial infections in European corn borer larvae held in the laboratory. JOUR. ECON. ENT. **45:** 48–51.

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# Effect of Weather Factors on the Toxicity of Certain Insecticides[1]

W. J. Mistric, Jr. and J. C. Gaines, *Texas Agricultural Experiment Station, College Station*

The adverse effect of wind during the application of insecticides has been recognized for many years. However, little work has been done to determine the effect of wind on the toxicity of insecticide deposits. Mistric & Gaines (1953a, 1953b) found that wind was an important factor in reducing the toxicity of many of the organic insecticides when applied to cotton as emulsion sprays. Simulated wind reduced the toxicity of toxaphene spray more than any of the other climatic factors studied. Toxaphene was extremely stable when exposed to natural climatic conditions in the absence of wind. Wind was not an important factor in reducing the toxicity of aldrin spray because it lost toxicity rapidly when exposed to natural climatic conditions even in the absence of wind. The results of this study created considerable interest relative to the effect of wind on insecticide toxicity. Considerable speculation also arose as to the manner in which wind reduces the toxicity of emulsion spray deposits of organic insecticides. Heretofore wind had not been considered as important a factor as temperature, sunlight or rain in reducing the toxicity of insecticide deposits. The effect of temperature, humidity, sunlight, dew, and rain on insecticide toxicity has been reported by Gaines & Dean (1949, 1950), Gaines & Mistric (1951, 1952), and Mistric & Gaines (1953a, 1953b).

The experiments reported herein were conducted at College Station, Texas during 1953 to obtain additional information regarding the effect of wind on the toxicity of certain insecticides.

Materials and Methods.—The following insecticides were included in these tests: toxaphene, dieldrin, endrin, and aldrin. All of these materials were applied as emuslion sprays to potted cotton plants. The sprays were made by diluting emulsifiable concentrates with water. The sprays were applied at a pressure of 60 pounds per square inch through two hollow cone nozzles at the rate of 5 gallons per acre. The plants were rotated through the spray as previously described.

The boll weevil, *Anthonomus grandis* Boh., and the salt-marsh caterpillar, *Estigmene acrea* (Drury), were used as test insects. Field-collected adult boll weevils and laboratory-reared third-instar larvae of the salt-marsh caterpillar were used in these tests.

The percentage mortalities were calculated by Abbott's formula. Comparable untreated checks were used in each test. Hygrothermographs were used to record the temperature and relative humidity throughout the investigation. The dosages are shown as pounds of active ingredients per acre. Survival records were made over a period of 5 days following the release of insects onto treated plants.

The methods used in determining the effect of simulated wind on insecticide toxicity were essentially the same as those used in 1952. Each lot of treated plants was divided into two groups immediately after the sprays had dried. One group of treated plants was placed in the greenhouse protected from any wind while the other group remained in the greenhouse under the same climatic conditions, except the plants were exposed to the action of simulated wind. In order to obtain a greater air movement, a 16-inch oscillating fan was substituted for the 12-inch fan used in 1952. The treated plants exposed to the wind were arranged in a single, straight row perpendicular to and about 3 feet in front of the fan and within the range of oscillation. An anemometer was placed near the plants in an exposed position. An accurate measurement of wind velocity was thus determined over a 24-hour exposure period. Twelve treated plants, consisting of three insecticide treatments each replicated four times, were placed in front of the fan during each boll weevil test. The treated plants were so arranged that the total wind movement directed onto four replicated plants was the same for each insecticidal treatment.

Results.—*Experiment 1.*—This test was conducted in the laboratory to determine the effect of wind on the toxicity of

[1] Technical Contribution No. 1943, Texas Agricultural Experiment Station in Cooperation with Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

**Table 1.—Laboratory cage toxicity tests for boll weevil control with insecticides applied as sprays. College Station, Texas. 1953.**

| TREATMENT | DOSE[1] | DATE | PER CENT MORTALITY | | | PER CENT REDUCTION IN TOXICITY | | |
|---|---|---|---|---|---|---|---|---|
| | | | Immediate Release | 24-Hour Delay | 24-Hour Delay Plus Simulated Wind | In 24 Hours | In 24 Hours Plus Wind | Due to Wind |
| Toxaphene | 1.0 | 9-4 | 85 | 65 | 74 | | | |
| | 1.0 | 9-23 | 67 | 67 | 34 | | | |
| | 1.0 | 10-2 | 15 | 24 | 0 | | | |
| | 1.0 | 10-8 | 79 | 61 | 30 | | | |
| | 1.0 | 10-14 | 61 | 54 | 13 | | | |
| | 1.5 | 10-16 | 36 | 42 | 22 | | | |
| | 2.0 | 10-29 | 18 | 16 | 18 | | | |
| | 3.0 | 11-6 | 28 | 39 | 19 | | | |
| Average | 1.4 | | 49 | 46 | 26 | 6 | 47 | 41 |
| Dieldrin | 0.20 | 9-4 | 100 | 72 | 56 | | | |
| | .15 | 9-23 | 76 | 64 | 40 | | | |
| | .15 | 10-2 | 81 | 6 | 15 | | | |
| | .15 | 10-8 | 100 | 76 | 30 | | | |
| | .15 | 10-14 | 97 | 89 | 33 | | | |
| | .15 | 10-16 | 67 | 39 | 10 | | | |
| | .10 | 10-29 | 68 | 12 | 3 | | | |
| | .10 | 11-6 | 55 | 22 | 20 | | | |
| Average | .14 | | 81 | 48 | 26 | 41 | 68 | 27 |
| Endrin | 0.20 | 9-4 | 100 | 95 | 98 | | | |
| | .15 | 9-23 | 100 | 96 | 84 | | | |
| | .10 | 10-2 | 94 | 33 | 0 | | | |
| | .10 | 10-8 | 100 | 100 | 93 | | | |
| | .10 | 10-14 | 100 | 89 | 43 | | | |
| | .05 | 10-16 | 88 | 26 | 0 | | | |
| | .05 | 10-29 | 57 | 0 | 8 | | | |
| | .05 | 11-6 | 57 | 30 | 11 | | | |
| Average | .10 | | 87 | 59 | 42 | 32 | 52 | 20 |

[1] Pounds active ingredients per acre.

toxaphene, dieldrin, and endrin to the boll weevil (Table 1). Three series of tests were conducted. One series consisted of releasing weevils onto treated plants in the laboratory immediately following the insecticide applications. Another series consisted of exposing treated plants for 24 hours in the greenhouse, and then releasing weevils onto these plants in the laboratory. The other series consisted of exposing treated plants to simulated wind in the greenhouse for 24 hours, and then releasing weevils onto these plants in the laboratory. The average maximum and minimum temperature in the laboratory during this experiment was 83° F. and 74° F., respectively. The average maximum and minimum relative humidity was 57 and 36 per cent, respectively. This experiment was conducted at the same time of the year using essentially the same methods as were employed in the 1952 experiments. The tests were replicated four times on each of eight different dates. Fifteen weevils were used in each of the 32 replications. The average percentages of mortality shown in table 1 are based on tests involving 480 weevils with each insecticidal treatment under each set of indicated conditions.

Toxaphene showed greater reduction in toxicity than dieldrin or endrin when treated plants were exposed to simulated wind (6.2 m.p.h.). However, in the absence of wind, the toxicity of toxaphene was reduced less than either dieldrin or endrin. Previous results indicated that the toxicity of toxaphene spray was not greatly reduced by rain or dew. These results indicate that toxaphene is extremely stable when exposed to natural climatic factors in the absence of wind. Wind, therefore, appears to be the most important climatic factor studied which reduces the toxicity of toxaphene. The toxicities of dieldrin and endrin were reduced to some extent by the simulated wind. When exposed to all climatic factors in the tests, the total reduction in the toxicities of toxaphene and endrin were approximately

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**Table 2.—Climatic conditions in the greenhouse during 24-hour delay period.[1] College Station, Texas. 1953.**

| Date | Wind Movement[2] | Degrees F. | | Per Cent Relative Humidity | |
|---|---|---|---|---|---|
| | | Max. | Min. | Max. | Min. |
| 9- 4 | 6.2 | 98 | 72 | 98 | 46 |
| 9-23 | 6.9 | 118 | 62 | 70 | 18 |
| 10- 2 | 6.7 | 112 | 75 | 98 | 32 |
| 10- 8 | 5.3 | 110 | 54 | 83 | 22 |
| 10-14 | 6.2 | 110 | 72 | 98 | 24 |
| 10-16 | 5.8 | 112 | 65 | 98 | 20 |
| 10-29 | 5.5 | 104 | 58 | 84 | 22 |
| 11- 6 | 7.1 | 105 | 73 | 76 | 54 |
| Average | 6.2 | 109 | 66 | 88 | 30 |

[1] As referred to in table 1.
[2] In miles per hour.

the same following a 24-hour exposure. The total reduction in the toxicity of dieldrin was slightly greater. Both the immediate and residual toxicity of endrin was slightly superior to that of dieldrin.

As shown in table 2, the temperature, relative humidity, and wind movement were approximately the same on each date when these tests were conducted. At least medium sunlight prevailed on each date when these tests were conducted. The effect of simulated wind on insecticide toxicity was determined under conditions of sunlight and wide ranges in temperature and relative humidity. It was noticed that the weevils were harder to kill with all of the insecticides on October 2, 16, 29 and November 6. The late season resistance of weevils to insecticides was probably responsible for the low mortalities recorded during the last three test dates. It was noted that dieldrin and endrin were considerably more effective in controlling the hardy late season weevils than toxaphene. Even though dieldrin and endrin gave good immediate control of hardy late season weevils, their residual toxicities to these weevils were greatly reduced.

The actual weevil mortalities produced by toxaphene and dieldrin following 24-hour delay periods with and without wind are strikingly similar. However, dieldrin was superior to toxaphene in killing weevils which were released onto plants soon after treatment. The toxicity of toxaphene was not greatly reduced following a 24-hour exposure of treated plants to natural climatic conditions in the absence of wind. The residual toxicity of toxaphene in general is therefore considered superior to that of dieldrin. Since toxaphene kills weevils slowly, the residual effectiveness of toxaphene is therefore an important factor in regard to the killing process. It has also been found (Mistric & Rainwater 1950) that weevils knocked down with toxaphene sometimes recover and again attack treated plants. Dieldrin, which possesses greater contact toxicity for weevils than toxaphene, kills weevils rather rapidly. It has also been found that weevils once knocked down with dieldrin seldom recover. It would therefore appear that the residual toxicity of dieldrin is not as important as in the case of toxaphene in actually killing boll weevils. The outstanding contact effect of dieldrin, its ability to kill weevils rather quickly, and a residual effectiveness which approaches that of toxaphene are the factors which are thought to be at least partially responsible for the superior weevil control sometimes obtained with dieldrin in comparison with toxaphene. Endrin is another insecticide which possesses a residual effectiveness for weevils comparable to that of toxaphene and dieldrin. However, endrin has not been studied sufficiently to warrant its inclusion in the preceding discussion.

*Experiment 2.*—This test was conducted in the laboratory to determine the effect of wind on the toxicity of toxaphene, aldrin, dieldrin, and endrin when used to control the salt-marsh caterpillar (Table 3). Three series of tests were conducted in a manner similar to that described in experiment 1. The average maximum and minimum temperature in the laboratory during this experiment was 85°F. and 76° F., respectively. The average maximum and minimum relative humidity was 52 and 36 per cent, respectively. The tests were replicated at least three times on each date. Ten salt-marsh caterpillar larvae were used in each replication. The average percentages of mortality shown in table 3 are based on tests involving 240 or more larvae with each insecticidal treatment under each set of indicated conditions.

The results of this experiment were strikingly similar to those obtained in experiment 1. Apparently the boll weevil and salt-marsh caterpillar respond alike to the residues of these insecticides following exposures to wind. It was also evident that the action of wind was not dependent on the dosage of insecticide applied. Different dosages of each insecticide were used against each insect. The dosages of

**Table 3.—Laboratory cage toxicity tests for salt-marsh caterpillar control with insecticides applied as sprays. College Station, Texas. 1953.**

| Treatment | Dose[1] | Date | Per Cent Mortality | | | Per Cent Reduction in Toxicity | | |
|---|---|---|---|---|---|---|---|---|
| | | | Immediate Release | 24-Hour Delay | 24-Hour Delay Plus Simulated Wind | In 24 Nours | In 24 Hours Plus Wind | Due to Wind |
| Toxaphene | 0.5 | 1-27 | 97 | 88 | 42 | | | |
| | .5 | 1-29 | 89 | 71 | 28 | | | |
| | 1.0 | 2-6 | 75 | 76 | 67 | | | |
| | .5 | 2-25 | 97 | 86 | 84 | | | |
| | .5 | 11-24 | 97 | 69 | 48 | | | |
| | .5 | 12-1 | 96 | 64 | 10 | | | |
| | .33 | 12-4 | 85 | 68 | 38 | | | |
| | .33 | 12-8 | 82 | 79 | 31 | | | |
| | .33 | 12-9 | 87 | 72 | 57 | | | |
| | .33 | 12-11 | 57 | 37 | 9 | | | |
| Average | .48 | | 86 | 71 | 41 | 17 | 52 | 35 |
| Aldrin | 0.5 | 1-27 | 90 | 63 | 33 | | | |
| | .5 | 2-25 | 97 | 81 | 64 | | | |
| | .5 | 11-24 | 97 | 7 | 36 | | | |
| | .5 | 12-1 | 100 | 35 | 46 | | | |
| | .33 | 12-4 | 52 | 12 | 13 | | | |
| | .33 | 12-8 | 85 | 41 | 10 | | | |
| | .33 | 12-9 | 75 | 23 | 35 | | | |
| | .5 | 12-11 | 57 | 34 | 17 | | | |
| Average | .44 | | 82 | 37 | 32 | 55 | 61 | 6 |
| Dieldrin | 0.5 | 1-27 | 100 | 100 | 97 | | | |
| | .33 | 11-24 | 100 | 76 | 75 | | | |
| | .33 | 12-1 | 100 | 65 | 56 | | | |
| | .20 | 12-4 | 96 | 76 | 19 | | | |
| | .15 | 12-8 | 86 | 61 | 17 | | | |
| | .15 | 12-9 | 87 | 55 | 37 | | | |
| | .20 | 12-11 | 52 | 34 | 24 | | | |
| Average | .27 | | 89 | 67 | 46 | 25 | 48 | 23 |
| Endrin | 0.3 | 1-29 | 97 | 97 | 78 | | | |
| | .3 | 2-6 | 90 | 84 | 59 | | | |
| | .25 | 11-24 | 100 | 83 | 89 | | | |
| | .25 | 12-1 | 100 | 76 | 69 | | | |
| | .15 | 12-4 | 92 | 71 | 39 | | | |
| | .08 | 12-8 | 86 | 39 | 23 | | | |
| | .08 | 12-9 | 93 | 47 | 28 | | | |
| | .15 | 12-11 | 89 | 32 | 0 | | | |
| Average | .20 | | 93 | 66 | 48 | 29 | 48 | 19 |

[1] Pounds active ingredients per acre.

insecticides used against the salt-marsh caterpillar differed greatly from those used for boll weevil control. Toxaphene showed greater reduction in toxicity than did aldrin, dieldrin, or endrin when treated plants were exposed to simulated wind (5.3 m.p.h.). However, in the absence of wind, the toxicity of toxaphene was reduced less than any of the other materials. These results again indicate that toxaphene is extremely stable when exposed to natural climatic conditions in the absence of wind. Wind, therefore, again appeared to be the most important climatic factor studied which reduced the toxicity of toxaphene. The toxicity of aldrin was reduced only slightly by simulated wind. However, the toxicity of aldrin was greatly reduced during a 24-hour exposure to natural climatic conditions even in the absence of wind. Wind, therefore, did not appear to be an important factor in reducing the toxicity of aldrin. Aldrin lost its toxicity in the absence of wind as rapidly as toxaphene, dieldrin, and endrin did in the presence of wind. The toxicities of dieldrin and endrin were reduced to some extent by the simulated wind. When exposed to all climatic factors studied in the tests, the total reduction in the toxicities of toxaphene, dieldrin, and endrin were approximately the same following

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**Table 4.—Climatic conditions in the greenhouse during 24-hour delay period.[1] College Station, Texas. 1953.**

| Date | Wind Movement[2] | Degrees F. | | Per Cent Relative Humidity | |
|---|---|---|---|---|---|
| | | Max. | Min. | Max. | Min. |
| 1-27 | 3.4 | 114 | 82 | 99 | 56 |
| 1-29 | 3.0 | 116 | 82 | 96 | 43 |
| 2- 6 | 3.3 | 116 | 84 | 99 | 64 |
| 2-25 | 3.2 | 104 | 80 | 99 | 70 |
| 11-24 | 6.5 | 112 | 74 | 84 | 30 |
| 12- 1 | 6.5 | 86 | 76 | 99 | 73 |
| 12- 4 | 6.8 | 97 | 73 | 96 | 37 |
| 12- 8 | 6.7 | 107 | 82 | 99 | 36 |
| 12- 9 | 6.7 | 86 | 73 | 99 | 52 |
| 12-11 | 6.7 | 92 | 75 | 99 | 51 |
| Average | 5.3 | 103 | 78 | 97 | 51 |

[1] As referred to in table 3.
[2] In miles per hour.

a 24-hour exposure. Wind alone had slightly less effect on the toxicity of endrin than on dieldrin.

The temperature, relative humidity, and wind movement were approximately the same on each date the tests were conducted (Table 4) with the exception that wind movement was increased beginning with the November 24 test. At least medium sunlight prevailed on each date when these tests were conducted. The effect of simulated wind on insecticide toxicity was determined under conditions of sunlight and wide ranges in temperature and relative humidity. An increase in wind movement caused a slight reduction in insecticide toxicity, at least within the range of wind velocities tested. At the dosages used, all of the insecticides were highly effective in controlling the salt-marsh caterpillar.

Extensive experiments were conducted during 1953 to determine the effect of wind on the toxicity of certain insecticides. The results of these experiments were in accord with the results of tests conducted previously at this station. Wind appeared to be one of the important climatic factors which reduces the toxicity of certain insecticide spray residues.

Since toxaphene is generally considered to be chemically stable and relatively nonvolatile, the removal of toxaphene emulsion spray deposits by wind was probably a mechanical process which may be due to the force of the wind and the rubbing together of the foliage of the cotton plant. However, it is also possible that some chemical mechanism as yet undiscovered may also be responsible for the deterioration of toxaphene spray residues when exposed to wind. Aldrin which is generally considered to be a relatively unstable chemical and which is fairly volatile was little affected by the action of wind. It is likely that wind might reduce the toxicity of a volatile material such as aldrin; however, under the conditions of these experiments the toxicity of aldrin was reduced so rapidly that it may not have been possible to adequately determine the effect of wind. Apparently wind did not greatly enhance the chemical removal of aldrin spray deposits nor did it have any appreciable effect on the mechanical removal of the deposits which remain independent of chemical deterioration. It is even more difficult to explain the removal of spray residues of dieldrin and endrin by wind because these two insecticides fall into a category intermediate between toxaphene and aldrin. In the case of dieldrin and endrin, it is likely that the reduction in the toxicities of these materials due to the effect of wind could be caused by either a chemical or a mechanical effect or a combination of the two.

SUMMARY.—Laboratory cage experiments were conducted to determine the effect of wind on the toxicity of emulsion sprays of toxaphene, dieldrin, and endrin when used to control the boll weevil. Similar experiments were also conducted to determine the effect of wind on the toxicity of toxaphene, aldrin, dieldrin and endrin when used to control the salt-marsh caterpillar. The results from the experiments with these two insects were strikingly similar. Simulated wind reduced the toxicity of toxaphene more than of the other materials tested. However, in the absence of wind the toxicity of toxaphene was reduced less than any of the other insecticides used. Wind, therefore, appeared to be the most important climatic factor studied which reduces the toxicity of toxaphene. Wind was not an important factor in reducing the toxicity of aldrin because aldrin lost its toxicity very rapidly even in the absence of wind. The toxicities of dieldrin and endrin were reduced appreciably by simulated wind. Both the immediate and residual toxicity of endrin was slightly superior to that of dieldrin. An increase in wind movement was found to slightly decrease the toxicity of insecticides, at least within the range of wind velocities tested. The effect of wind was not dependent on the dosage of insecticides applied in these tests.

LITERATURE CITED

Gaines, J. C., and H. A. Dean. 1949. Effect of temperature and humidity on the toxicity of certain insecticides. JOUR. ECON. ENT. 42(3): 429.

Gaines, J. C., and H. A. Dean. 1950. Effect of climatic factors on the toxicity of certain insecticides. JOUR. ECON. ENT. 43(5): 602.

Gaines, J. C., and W. J. Mistric, Jr. 1951. Effect of rainfall and other factors on the toxicity of certain insecticides. JOUR. ECON. ENT. 44(4): 580.

Gaines, J. C., and W. J. Mistric, Jr. 1952. Effect of environmental factors on the toxicity of certain insecticides. JOUR. ECON. ENT. 45(3): 409.

Mistric, W. J., Jr., and J. C. Gaines. 1953a. Effect of wind and other factors on the toxicity of certain insecticides. JOUR. ECON. ENT. 46(2): 341.

Mistric, W. J., Jr., and J. C. Gaines. 1953b. The toxicity of certain insecticides to the overwintered boll weevil. JOUR. ECON. ENT. 46(2): 350.

Mistric, W. J., Jr., and C. F. Rainwater. 1950. Laboratory experiments to determine the insecticidal action of several organic insecticides against boll weevil. JOUR. ECON. ENT. 43(6): 892.

# Insecticidal Control of the Corn Rootworm in 1953[1]

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The corn rootworm, *Diabrotica longicornis* (Say), continues to be an important economic insect in the Corn Belt in these days of intensive corn production on high priced land. The Iowa work on the control of this pest prior to the 1953 growing season has been reported in an earlier paper (Cox & Lilly 1953). This work was continued actively in 1953, and is reported here because of the continued interest in the problem and the new findings of the past season.

MATERIALS AND METHODS.—The insecticides used in 1953 included endrin, isodrin, and toxaphene, in addition to the five others previously tested. New formulations tried for the first time in 1953 included 30–60 mesh granulated *Attaclay* preparations of aldrin, heptachlor, and chlordane, respectively. The aldrin was on *RVM-A Attaclay*, while heptachlor and chlordane were on *LVM-AA*.

Five new methods of application or variations of method of application were tried for the first time in Iowa in 1953. These were: (1) Spraying the old cornstalks in the spring and disking them down prior to spring plowing. (2) Broadcast sprays applied to plowed land and disked in before planting with a lister. (3) Insecticide sprays applied in different ways to protect corn planted on the tops of ridges from rootworm infestation. (4) Banding low-gallonage sprays along planter wheel tracks before emergence of corn and harrowing to work the insecticide into the soil. (5) Airplane applications of insecticide shortly after planting.

The methods of taking the data were essentially the same as those previously reported (Cox & Lilly 1953). The method of counting the rootworms in and around the roots was the same as in previous years, except that some refinements were made in the mechanics of the procedure (Figure 1). Root-lodging information was obtained as in previous years, except that 160 row-feet per replicate were usually used as a sample instead of 80 row-feet. For purposes of analyzing the 1953 data the plants were classified as "not lodged," meaning plants leaning less than 30°, and "lodged," meaning plants leaning more than 30° from the vertical position. To obtain yield estimates the usual procedure was to select and hand-harvest 160 row-feet in each plot, at a location selected at random.[3] All yields are recorded in bushels per acre of corn at 15.5 per cent moisture.

The 1953 experiments include four in which broadcast applications were used, and four in which the insecticides were banded along the rows. These are described in detail below.

BROADCAST APPLICATIONS.—(1) *Pioneer Hybrid Company, Polk County* (Table 1). This is a long-time experiment, initi-

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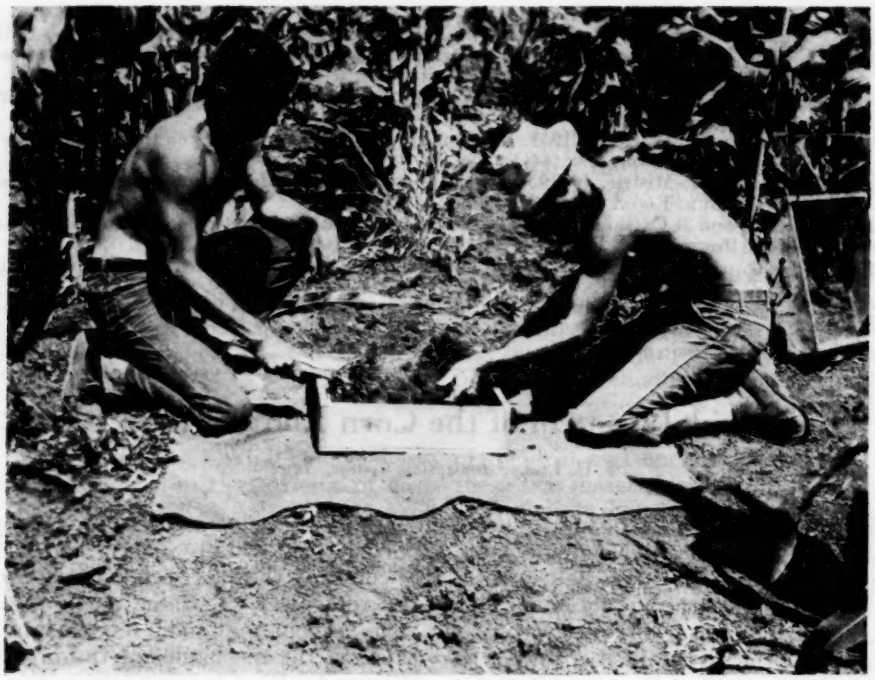

FIG. 1.—Making corn rootworm counts. The roots have been taken up and are being cleaned in preparation for dissection. The soil from an area about 14 inches in diameter and 8 inches deep is passed through a ¾-inch screen onto a tarpaulin where it is carefully searched for rootworms. As many as 270 rootworms have been found in a two-plant hill by this method.

ated in 1952, to determine how long a single heavy application of rootworm insecticide may be expected to remain effective. The work was done in cooperation with the Pioneer Hybrid Seed Corn Company in a field near Johnston, Iowa. It had been in corn continuously for at least 10 years prior to 1952, and had shown a fairly heavy rootworm infestation in 1951. The experiment was set up in a randomized complete block design consisting of five treatments, including the untreated control, replicated four times. The individual plots were 27×54 feet, and were marked for spraying by means of tightly strung twine. Hand-sprayers were used to make the applications, and about 2 gallons of water were used as the carrier for the proper quantity of insecticide concentrate on each plot. Emulsifiable concentrates of aldrin, chlordane, dieldrin and heptachlor, respectively, were the insecticides used. The field was disked and sprayed on April 30, 1952, after which the whole area was re-disked.

Root-lodging and yield data were taken from this experiment in September of 1952 and October of 1953. The central area of each plot, consisting of a section four hills wide and 10 hills long, was the portion from which all data were taken to avoid any possibility of border contamination.

(2) *Howard Waters field—Des Moines County* (Table 2). In this experiment four insecticides were tested in a very heavily infested but fertile field. The insecticides were aldrin, heptachlor, BHC and endrin, respectively. The rate was 1 pound of active ingredient per acre, applied in about 10 gallons of water. An untreated control was included in the randomized complete block design employed. The plots were 20 feet or six corn rows wide and 80 rods long.

These applications were made before planting, but in a different way from any previous experiment. The sprays were applied to the 1952 corn stalks and soil on May 15. The field was disked immediately after spraying, plowed on the following day, and planted on May 21. Diggings and counts were made to determine the rootworm populations present on July 8, 9, and 10.

(3) *John Beckett field—Page County* (Table 3). The treatments in this experi-

ment were aldrin, heptachlor, and BHC at 1 pound of active ingredient per acre, respectively, along with an untreated control. They were applied with a broadcast sprayer on May 8, 1953, and disked in immediately. The field was planted with a two-row lister on May 9. Each treatment was replicated three times in a completely randomized design.

It seemed questionable whether broadcast spraying before listing would do the job, because of the height of the lister-made ridges and the fact that most of the insecticide would be in the ridges instead of around the roots of the plants when they were small. This distribution changed as the season progressed because the ridges were eventually leveled off by cultivation.

(4) *John Buckles farm—Story County* (Table 4). This was an experiment in which three different levels of aldrin were applied by air for corn rootworm control. It was a 25-acre field in which the treated swaths were 50 feet wide and the untreated controls were 150 wide, so as to avoid the effects of spray drift. The plan was to spray at the rate of 0.5 pound of aldrin per acre per application. In this way applications of 0.5, 1.0, and 1.5 pound per acre would be obtained by flying over the respective swaths one, two, or three times. The experiment was laid out with four replications.

Spraying was done on May 25, 1953, after planting and just as the seedlings were starting to emerge. The applications ran heavier than planned, resulting in actual dosages of 0.67, 1.34, and 1.91 pounds of aldrin per acre, respectively. The field was rotary-hoed twice on the following day, in order to work the insecticide into the soil as much as possible.

APPLICATIONS BANDED ALONG THE ROWS.—(1) *E. L. Killius farm—Story County* (Table 5). Six insecticides and an untreated control were used in this experiment. It was a farmer-planted, field-scale experiment in which the sprayed plots were eight rows wide and the untreated controls were four rows wide. All rootworm counts were made in the two center rows of the respective plots. A randomized complete block experimental design with four replications was employed.

The objective of this experiment was two fold: (1) To compare some "new" rootworm insecticides (endrin, isodrin, and toxaphene) with some of those tested in previous years, and (2) to see if a post-planting surface spray application could be made to work satisfactorily in rootworm control. Prior attempts of this kind had been only partially effective in Iowa (Cox & Lilly 1953).

The insecticides used were aldrin, heptachlor, toxaphene, chlordane, endrin, and isodrin. The application rate was 1 pound of active ingredient per acre, in $3\frac{1}{4}$ gallons of water. These sprays were banded over the rows in bands about 6 inches wide. Thus the area actually sprayed received nearly seven times the dosages of both water and insecticide per acre given in table 5, since the corn was planted in 40-inch rows. The field had been planted without treatment on May 15, using a two-row tractor-drawn planter with rubber-tired covering wheels. These wheels left the soil firm and somewhat depressed over the rows.

These insecticide treatments were applied on May 18, using a planter-mounted Broyhill sprayer. The same planter and tractor were used as for planting, but in this case the planter was used merely to carry the sprayer. Few farmers would use this procedure commercially, but many would be interested in surface spraying over the rows with a boom-type sprayer soon after planting if it would give control. This appears to be a comparable method, hence the results of this experiment appear to have considerable practical interest. After spraying, the field was harrowed crosswise to cover the insecticide and cut down on its volatilization.

(2) *Herbert Arthur field—Wright County* (Table 6). This was the only experiment with insecticide-fertilizer mixtures used as starter fertilizers in 1953. Aldrin, chlordane, and heptachlor were used, and in all cases the insecticides were formulated on 30–60 mesh granulated *Attaclay*. The regular 6-24-12 fertilizer base was used as the control. This was a farmer-planted field in which a four-row planter was used. A different mixture was put into each of the four starter fertilizer boxes. Hence the plots consisted of one row each, as had been previously described for the Miller field at Ames in 1951 (Cox & Lilly 1953).

The intention here was to use the three insecticides at 0.5 pound per acre banded along the rows in the starter fertilizer mixtures. This level was obtained with hepta-

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chlor, but exceeded with both aldrin and chlordane. The aldrin was used at 0.6 pound per acre, while the chlordane was applied at 0.8 pound per acre. These differences were unintentional but the results are instructive anyway. Unfortunately the same materials were not used in the regular powdered formulations at comparable dosages in this field.

(3) *Agricultural Engineering Research farm—Story County* (Table 7). This experiment was carried out in cooperation with Agricultural Engineers, E. V. Collins of Iowa State College, and Walter Lovely of the U. S. Department of Agriculture. All insecticide treatments consisted of aldrin at 1 pound actual per acre, and were applied by the Agricultural Engineers with their equipment. The variable factor under study was the method of application. An additional variable was the cultural management. The Agricultural Engineers are working with corn planted on tops of ridges, i.e., essentially the reverse of listing. In this experiment the corn was planted in this way, with the exception of one flat-planted treatment included for comparison. Both the insecticide and the cultural treatments are described in table 7.

(4) *F. A. Barrett farm—Dallas County* (Table 8). This experiment was an attempt to use post-planting applications of insecticides for corn rootworm control. The 30–60 mesh granulated *Attaclay* formulations of aldrin, heptachlor, and chlordane, respectively, were mixed with the side-dress fertilizer. These insecticide-fertilizer mixtures were applied with a cultivator-mounted fertilizer distributor when the corn, then about 12 inches tall, was cultivated on May 15.

The base fertilizer in this experiment was a 4-12-8 formulation. The insecticides were 25 per cent heptachlor, 29.9 per cent aldrin, and 40 per cent chlordane, respectively. In this case all were mixed and applied so as to give a dosage rate of $\frac{7}{12}$ pound per acre. The fertilizer spouts on this machine emptied just behind the cultivator shovel nearest to the row and about 4 inches from the center of it. However they applied the mixture only on one side of the row, instead of on both sides as with standard planter-mounted starter fertilizer attachments. Immediately after application the insecticide-fertilizer mixes were well covered with soil thrown toward the rows by the other cultivator shovels. This method of application would appeal to many farmers if it would give control.

RESULTS AND DISCUSSION.—Table 1 summarizes the results obtained in the Polk County long-time experiment in 1952 and 1953. It includes only records on root-lodging and yields, since rootworm counts were not made in this field either year. The most notable difference between the 2 years is the relative absence of lodging following all treatments, including the unsprayed plots, in 1953. This was characteristic of most of the experimental fields in 1953, apparently because of the dry conditions that prevailed in late summer and fall. The dry, hard ground was not conducive to lodging, even where rootworm damage was heavy. The yields were excellent throughout this experimental area during both seasons.

**Table 1.—Effects of four insecticides each applied broadcast at 5 pounds per acre and disked into plowed ground before planting in 1952, on root-lodging and corn yields in 1952 and 1953, respectively. Pioneer Hybrid Company, Polk County, Iowa.**

| | PER CENT OF PLANTS ROOT-LODGED OVER 30° IN 40 HILLS | | YIELDS IN BU./ACRE | |
|---|---|---|---|---|
| TREATMENT | 1952 | 1953 | 1952 | 1953 |
| Untreated | 54.0 | 7.0 | 101.9 | 99.2 |
| Aldrin | 3.2 | 0 | 109.7 | 113.2 |
| Chlordane | 6.0 | 0 | 107.2 | 110.3 |
| Dieldrin | 3.5 | 0 | 112.0 | 111.5 |
| Heptachlor | 3.7 | 0 | 110.1 | 113.2 |
| Check vs. treatments | ** | ** | * | ** |
| Among treatments | n.s. | n.s. | n.s. | n.s. |

** Significant at 1% level by F test.
* Significant at 5% level by F test.
n.s. Not significant at 5% level by F test.

It will be noted that the differences between the untreated control and the treatments were significant to at least the 5 per cent level in all cases. However there were no significant differences between treatments on either lodging or yield in either year.

The experiment reported in table 2 was situated where a heavy and uniform rootworm infestation appeared in a fertile field. The insecticides all gave good commercial control, and the results were striking when the field was observed anytime

**Table 2.—Effects of four insecticides, each sprayed over old corn stalks at 1 pound per acre and disked in before spring-plowing, on rootworm populations, root-lodging, and corn yields. Howard Waters farm, Des Moines County, Iowa. 1953.**

| Treatment | Rootworms in 24 Hills | Per Cent of Plants Root-Lodged Over 30° in 640 Row-Ft. | Yield in Bu./Acre |
|---|---|---|---|
| Untreated | 3702 | 79.0 | 49.2 |
| Aldrin | 932 | 4.0 | 97.5 |
| Heptachlor | 146 | 0.14 | 100.7 |
| Endrin | 269 | 0.16 | 96.3 |
| BHC (g.i.) | 206 | 0.29 | 107.7 |
| Check vs. treatments | ** | ** | ** |
| Among treatments | ** | n.s. | n.s. |

**Table 3.—Effects of three insecticides, each sprayed broadcast at 1 pound per acre and disked into plowed ground just before planting with a two-row lister, on rootworm counts, root-lodging, and corn yields. John Beckett farm, Page County, Iowa. 1953.**

| Treatment | Rootworms in 18 Plants | Per Cent of Plants Root-Lodged More Than 30° in 960 Row-Feet | Yield in Bu./Acre |
|---|---|---|---|
| Untreated | 287 | 9.62 | 62.6 |
| Aldrin | 187 | 1.60 | 67.6 |
| Heptachlor | 136 | 0.22 | 64.3 |
| BHC (g.i.) | 56 | 0.11 | 63.2 |
| Check vs. treatments | * | ** | ** |
| Among treatments | n.s. | n.s. | n.s. |

during late summer and fall.

It will be noted that the differences between the untreated control and the four insecticide treatments are highly significant on the basis of rootworm counts, root-lodging, and yields. In considering differences between treatments, no significant differences were observed, except in the rootworm counts where aldrin was noticeably below the other three insecticides. This may have been due to a formulation which did not emulsify well, and consequently gave poorer results than are ordinarily obtained with this insecticide.

This experiment is important because it involved a time and method of application that had not been tried previously, i.e., spraying the insecticides over the old corn stalks before plowing. This appeals to farmers because the ground is relatively firm before plowing, and the old rows serve admirably as markers in operating a sprayer. A similar experiment was set up in Butler County in 1953 but weed growth in this second field was so bad that rootworm counts and other data were not taken there. However observations indicated that the rootworm control obtained was essentially similar to that reported in table 2.

Table 3 shows the results of the first experiment where insecticides were applied broadcast on plowed land before the crop was planted with a lister. The results obtained were not as good as would be expected from these same treatments with surface-planted corn. However, the differences were significantly in favor of the treatments over the check at the 5 per cent level for the root-worm counts, and at the 1 per cent level for the lodging records. The yields ran surprisingly close together and showed no significant differences. Probably this is not the most efficient way of applying a rootworm insecticide where corn is listed, but it appears to be a means by which at least partial control can be economically obtained.

The results presented in table 4 are not sufficient to warrant statistical analysis or final conclusions. They are included here to show that rootworm control by means of airplane application appears to be a possibility. These results are particularly encouraging when we recall that most post-planting rootworm applications have not proven satisfactory. This type of treatment would appeal to some large-scale farmers, particularly in wet seasons when spraying with a ground machine is not feasible.

Results from the field of third-year corn reported in table 5 showed a much lighter rootworm infestation than was anticipated on the basis of previous history on this farm. However the results with this low population were surprisingly consistent, and the differences in rootworm counts proved significant both between the control and the treatments and among treatments. Differences in yields were not

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**Table 4.—Effects on corn rootworm population of three levels of aldrin in low-gallonage spray applied by air. John Buckles farm, Story County, Iowa. 1953.[1]**

| TREATMENT | REPLICATE | TOTAL ROOTWORMS IN SIX 3-PLANT HILLS |
|---|---|---|
| Control Untreated | 1 | 162 |
| | 2 | 489 |
| | Total | 651 |
| 0.67 lb./acre of aldrin (once over) | 1 | 69 |
| | 2 | 74 |
| | Total | 143 |
| 1.34 lb./acre of aldrin (twice over) | 1 | 30 |
| | 2 | 80 |
| | Total | 110 |
| 1.91 lb./acre of aldrin (three times over) | 1 | 37 |
| | 2 | 54 |
| | Total | 91 |

[1] Airplane spraying by courtesy of Charles Laverty, Indianola, Iowa.

significant, but the untreated control showed significantly more root-lodging than the treated plots.

Table 6 summarizes the only 1953 experiment in which insecticides were mixed with starter fertilizer. It was the first test of a 30–60 mesh granulated formulations for this use. Unfortunately comparisons were not made with the same dosages of the same materials in wettable powder formulations.

**Table 5.—Effects of seven insecticides, each sprayed over the planter wheel tracks in 6-inch bands at 1 pound per acre and harrowed in 3 days after planting, on rootworm populations, root-lodging, and corn yields. E. L. Killius farm, Story County, Iowa, 1953.**

| TREATMENT | ROOTWORMS IN 12 HILLS | PER CENT OF PLANTS ROOT-LODGED OVER 30° IN 640 ROW-FT. | YIELD IN BU./ACRE |
|---|---|---|---|
| Untreated | 627 | 13.85 | 62.8 |
| Aldrin | 92 | 0 | 68.0 |
| Heptachlor | 59 | 0 | 65.8 |
| Toxaphene | 270 | 0.80 | 69.6 |
| Chlordane | 103 | 0 | 61.2 |
| Endrin | 58 | 0 | 74.8 |
| Isodrin | 57 | 0 | 74.3 |
| Check vs. treatments | ** | ** | n.s. |
| Among treatments | ** | n.s. | n.s. |

**Table 6.—Effects of three insecticides on 30–60 mesh granulated formulations mixed with commercial fertilizer and used as starter fertilizers at time of planting, on rootworm populations, root-lodging, and corn yields. Herbert Arthur farm, Wright County, Iowa. 1953.**

| TREATMENT | ROOTWORMS IN 24 THREE-PLANT HILLS | PER CENT OF PLANTS ROOT-LODGED OVER 30° IN 320 ROW-FT. | YIELD IN BU./ACRE OF CORN AT 15.5% MOISTURE |
|---|---|---|---|
| Control Fertilizer only | 476 | 0 | 108.5 |
| Heptachlor 0.5 lb./acre | 115 | 0 | 110.9 |
| Aldrin 0.6 lb./acre | 114 | 0 | 109.7 |
| Chlordane 0.8 lb./acre | 152 | 0 | 90.9 |
| Check vs. treatments | ** | — | n.s. |
| Among treatments | n.s. | — | ** |

The rootworm counts in the Arthur field show a highly significant difference between the untreated control plots and the treated plots. The differences in yields showed chlordane-treated plots significantly lower than the others. There was no indication of phytotoxicity and a satisfactory explanation of this result is lacking. Although direct comparisons were not made in this experiment, the rootworm control obtained with each of the three insecticides used was lower than normally expected from the same levels of these chemicals applied in starter-fertilizer mixtures.

The results of the experiment reported in table 7 involved the application of aldrin by four different procedures carried out by the Agricultural Engineers at Iowa State College. It will be noted that the rootworm counts show a highly significant difference between the aldrin-treated plots and the untreated control. However the yield data show no significance between the yields of the unsprayed control plot and the insecticide-treated plots, with the exception of the last treatment where the corn was surface-planted on level ground instead of on the tops of ridges. The lower yield from the latter treatment was probably due to differences in fertilization and cultivation inherent in the experiment, rather than to the fact that the

Table 7.—Effects of aldrin at 1 pound per acre, applied in four different ways and with two cultural methods, on rootworm counts, and corn yields. Agricultural Engineering Research Farm, Story County, Iowa. 1953.

| ALDRIN APPLICATION AND CULTURAL TREATMENT | ROOTWORMS IN 24 HILLS | YIELD IN BU./ACRE |
|---|---|---|
| Ridge-planted | | |
| Control (no insecticide) | 732 | 69.6 |
| Applied with planter-mounted Broyhill sprayer | 45 | 73.6 |
| Sprayed in 10-inch bands on ridges and worked in with a roller | 33 | 74.3 |
| Sprayed broadcast on plowed soil before ridging and planting | 7 | 78.7 |
| Regular surface-planted | | |
| Applied with planter-mounted Broyhill sprayer | 34 | 64.7 |
| Check vs. treatments | ** | n.s. |
| Among treatments | n.s. | * |

corn was planted differently from that in the other four treatments.

The data reported in table 8 are disappointing in that they do not show any significant difference between the untreated control and the treatments, either on the basis of rootworm counts or in crop yields. However, this is in accord with previously reported data from deep-placement applications of fertilizer after the corn was up (Cox & Lilly 1953).

Table 8.—Effects of three insecticides each at 7/12 pound per acre in 30–60 mesh granulated formulations, mixed with commercial fertilizer and used as side-dressed applications at first cultivation, on rootworm populations, root-lodging, and corn yields. F. A. Barrett farm, Dallas County, Iowa. 1953.

| TREATMENT | ROOTWORMS IN 18 TWO-PLANT HILLS | PER CENT OF PLANTS ROOT-LODGED OVER 30° IN 480 ROW-FT. | YIELD IN BU./ACRE |
|---|---|---|---|
| Control | | | |
| Fertilizer only | 928 | 2.85 | 80.7 |
| Aldrin | 841 | 0 | 74.7 |
| Heptachlor | 573 | 0 | 77.0 |
| Chlordane | 532 | 0 | 74.5 |
| Check vs. treatments | n.s. | — | n.s. |
| Among treatments | n.s. | — | n.s. |

SUMMARY AND CONCLUSIONS.—Heptachlor, aldrin, gamma isomer of BHC. dieldrin, and probably endrin and isodrin, are about equally effective, pound for pound, for control of corn rootworm. Chlordane appears to be a little less effective, while toxaphene at the same rate of application appears to be considerably less effective.

Five methods of application not previously tested were successful or promising when used for the first time in 1953. These were: (a) broadcast spraying followed by disking prior to spring plowing, (b) spraying over planted rows before emergence and harrowing crosswise to retain the spray residues, (c) broadcast spraying and disking in before planting with a lister, (d) low-gallonage spraying by air followed by rotary-hoeing, and (e) aldrin applied by different procedures on ridge-planted corn.

Aldrin, heptachlor, dieldrin, and chlordane when sprayed broadcast on plowed land at 5 pounds per acre and disked in, gave significantly less root-lodging and significantly higher yields than the untreated plots in the year of application (1952), and also a year later without additional treatments.

Good commercial control of severe rootworm infestations and large increases in yield were obtained with surface applications of heptachlor, endrin, BHC and aldrin disked in and plowed under in the spring.

Significant reductions in rootworm numbers and root-lodging were obtained in listed corn where the planting was preceded by broadcast spray applications of gamma isomer of BHC, heptachlor and aldrin, respectively, at 1 pound per acre, broadcast and disked in. Banding low-gallonage sprays over the planted rows and harrowing in gave good commercial control with heptachlor, endrin, isodrin, aldrin or chlordane.

Starter fertilizer mixtures containing aldrin, heptachlor, or chlordane in 30–60 mesh granulated *Attaclay* formulations gave commercial control of a light rootworm infestation, but were less effective than anticipated.

Commercial control of rootworms was obtained with 1 pound of aldrin per acre applied to ridge-planted corn by three different procedures, and on regular surface-planted corn by one method.

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LITERATURE CITED

Cox, H. C., and J. H. Lilly. 1953. Chemical control of the corn rootworm. JOUR. ECON. ENT. 46(2): 217–24.

# The Effect of DDT Sprays on Mite and Aphid Populations on Elms

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The increase in mite populations following the use of DDT has been observed and studied by a number of workers. Steiner *et al.* (1944) observed large populations of red spider, *Tetranychus* sp., on apples at harvest and under the bark of the trees sprayed with DDT, while they had difficulty in finding mites on trees not sprayed with DDT. They also noted the absence of the mite predator, *Stethorus punctum* (Lec.), in the DDT plots but an abundance of this predator in plots sprayed with lead arsenate and nicotine. Hough *et al.* (1945) also noted increases in mite populations in apple orchards after the use of DDT. While Dean (1947) concluded that infestations of the European red mite were not associated with DDT in apple orchards, Ortega (1953) presented data showing greatly increased infestations of the European red mite and the walnut aphid following applications of DDT to walnut trees. Newcomer & Dean (1953) found that DDT killed the parasite, *Aphelinus mali* (Hald.), allowing a tremendous increase in populations of *Erisoma lanigerum* (Hausm.). Application of DDT for mosquito control was the inadvertent cause for increased populations of *Tetranychus bimaculatus* Harvey on a hedge of *Hydrangea arborescens* and a heavy infestation of *Paratetranychus bicolor* Banks on oaks and maples, according to Bromley (1948).

Applications of DDT to elms on the campus of the University of Illinois were begun in 1949 to control the leafhopper, *Scaphoideus luteolus* Van D., the vector of phloem necrosis. The spray program called for two foliar treatments each year with 6 per cent DDT applied by mist blower. General appearance of the trees in the late summer of 1951 indicated mite damage. This paper reports a study during the summers of 1952 and 1953 of populations of the mite, *Tetranychus bimaculatus* Harvey, and the aphid, *Tuberculatus ulmifolii* (Monell), on a plot of sprayed and on a plot of unsprayed trees.

SAMPLING TECHNIQUE.—A plot of 12 trees which had been sprayed in 1949, 1950, and 1951, along one street was left unsprayed in 1952 and 1953. A similar plot of 10 trees close by was sprayed in all 5 years.

Sample leaves were knocked off the trees with 20- to 30-gram stones shot from a specially constructed sling shot. Thirty-two whole leaves were collected from each tree at weekly intervals throughout the summer. Each leaf sample was placed in a paper bag and taken to the laboratory where the mites were removed with a Henderson (1943) machine. Samples taken by the sling-shot method, with a pole pruner, and by climbing gave essentially the same mite counts, but some reduction in aphids was noted on leaves obtained with the sling shot. Nevertheless, we feel that the aphid counts from leaves sampled in this manner are valid for comparative purposes. The mites and aphids were counted on a 1/32-sector of the glass disk from the brushing machine to give a "per leaf" record without calculation.

MITE POPULATIONS ON SPRAYED AND UNSPRAYED TREES.—In 1952 the plot selected for treatment was sprayed May 27 and July 24. The mite infestation developed slowly from the last week of June until about the first of August, and then skyrocketed from an average of about seven mites per leaf to nearly 60 per leaf in less than 2 weeks, figure 1. The population reached a peak of 67 mites per leaf on August 15 and declined gradually throughout September. By contrast the population on the unsprayed trees attained a peak of only 12 mites per leaf and this occurred on July 29. Afterwards the population declined until it was zero on August 26, about the time at which the population on the sprayed plot was at its peak. The population on the unsprayed plot remained at zero for the rest of the season.

The same two plots of trees were sampled in 1953. On the sprayed plot, treated

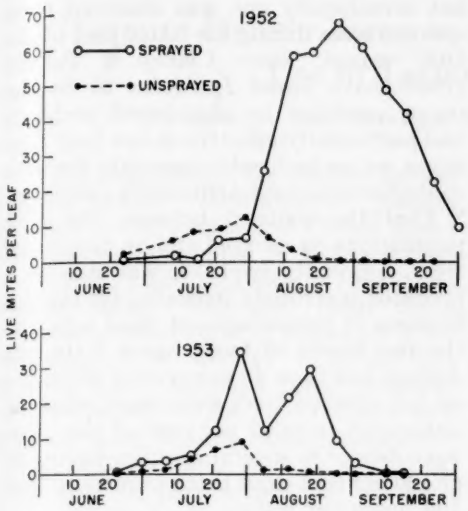


FIG. 1.—The mite population on an unsprayed plot of elms and on a plot sprayed twice with DDT in 1952, above. The mite population on the same two plots in 1953, below, when the treated plot was sprayed once with DDT supplemented with Aramite.

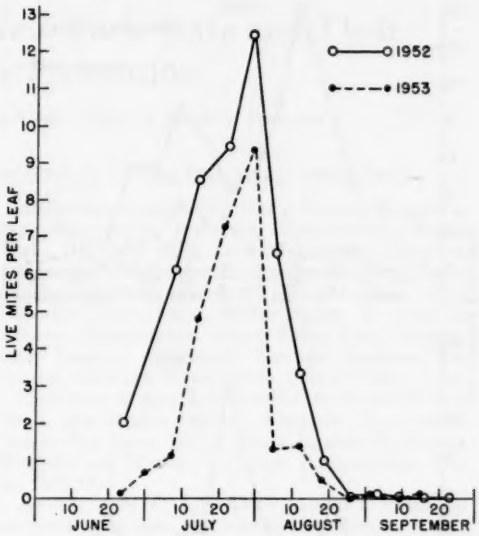


FIG. 2.—Showing the similarity of mite populations on the unsprayed plot of elms in 1952 and 1953.

only once, June 10, the DDT spray was supplemented with 6 pounds of Aramite 15-W per 50-gallon tank. The peak population on the sprayed trees came almost a month earlier in 1953 and reached a magnitude of only 34 mites per leaf, figure 1. There was an irregular decline that reached almost zero by September 10. The difference between the 1953 and 1952 population patterns on the sprayed trees may have been due partly to the use of an acaracide in 1953 and partly to the omission of the second DDT spray the same year.

Of considerable interest is the fact that the population patterns on the unsprayed trees were very similar for the 2 years, figure 2. The peaks occurred at the same time of year, and furthermore, there was a difference of only three mites per leaf in

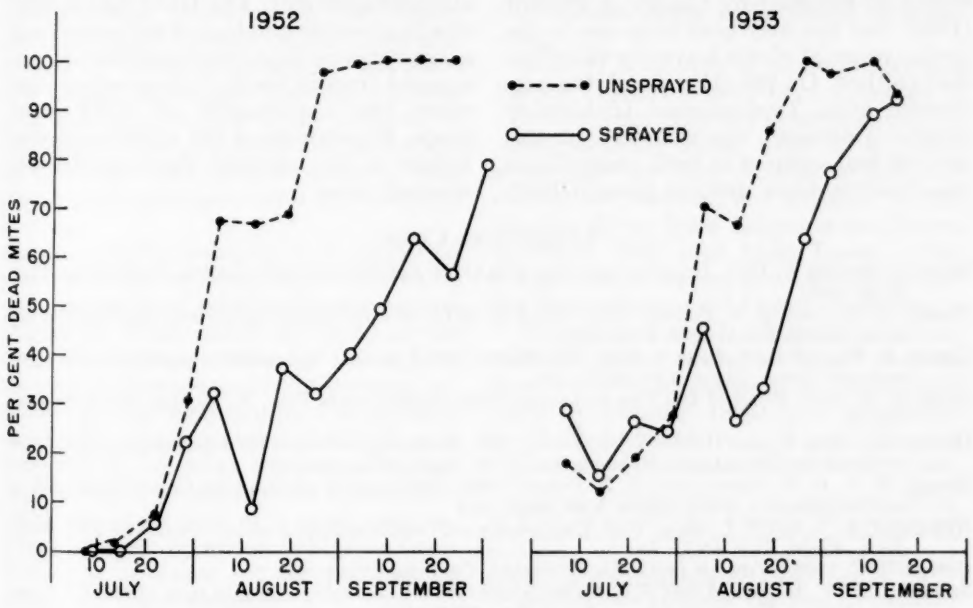


FIG. 3.—Showing the percentage of dead mites on unsprayed plots of elms and on plots sprayed with DDT.

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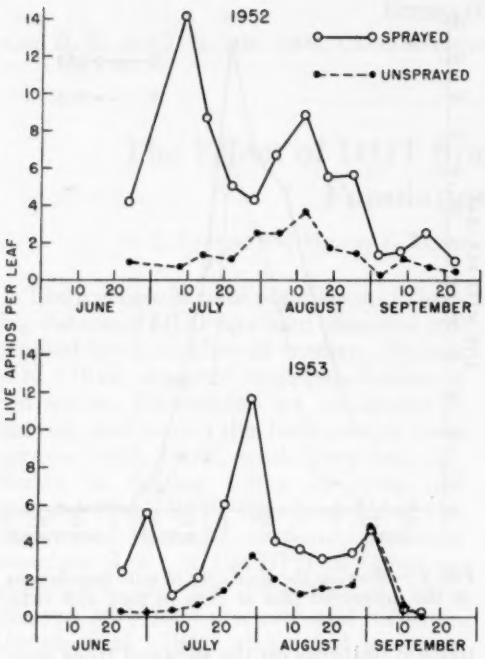


FIG. 4.—Showing the populations of aphids on plots of elms sprayed with DDT and on unsprayed plots.

the magnitude of the peaks. It seems evident that the mites on the unsprayed trees were controlled by natural agencies. Unfortunately, quantitative data on this point were not obtained. The ladybeetle, *Stethorus punctum* (Lec.), was rarely observed as reported by Clancy & Pollard (1948), but this may have been due to the jarring removal of elm leaves by the slingshot method. On the other hand, the predaceous mite, *Typhlodromus* (*Iphidulus*) *fallacis* (Garman), was observed on unsprayed leaf samples in both years. None was observed from sprayed trees in 1952, but occasionally one was observed from sprayed trees during the latter part of the 1953 season. Since Clancy & Pollard (1952) have found *Iphidulus* to be the major predator in abandoned orchards and particularly effective at low host densities, we are inclined to associate the mite control on unsprayed elms with *Iphidulus*.

That the contrast between the mite populations on sprayed and on unsprayed trees, especially in 1952, was due to a predator is strongly indicated by the differences in percentages of dead mites on the two blocks of trees, figure 3. In late August less than 40 per cent of the mites on the sprayed trees were dead, while on unsprayed trees 97 per cent of the mites were dead. On several samples having 97 or 100 per cent dead there were more than 100 mites per leaf.

APHID POPULATIONS ON SPRAYED AND UNSPRAYED TREES.—That more aphids were present on sprayed than on unsprayed trees during both 1952 and 1953 is evident from figure 4. The infestation patterns on the sprayed trees were irregular but those on the unsprayed trees were somewhat similar in the 2 years and of the same order of magnitude.

SUMMARY.—Populations of the two-spotted mite, *Tetranychus bimaculatus* Harvey, and the aphid, *Tuberculatus ulmifolii* (Monell), were studied for 2 years on a plot of elms sprayed with DDT and on an unsprayed plot. The DDT was conducive to a terrific build-up of mites reaching a density more than five times that on unsprayed trees in the first observation year when two applications of DDT were made. Populations of the aphid were also higher on the sprayed than on the unsprayed trees.

## LITERATURE CITED

**Bromley, Stanley W.** 1948. Mosquito spraying with DDT and the two-spotted mite. JOUR. ECON. ENT. **41**(3): 508.

**Clancy, D. W.,** and H. N. Pollard. 1948. Effect of DDT on several apple pests and their natural enemies. JOUR. ECON. ENT. **41**(3): 507.

**Clancy, D. W.,** and H. N. Pollard. 1952. The effect of DDT on mite and predator populations in apple orchards. JOUR. ECON. ENT. **45**(1): 108.

**Dean, R. W.** 1947. Effect of DDT on pests other than codling moth. Proc. N. Y. State Hort. Soc. pp. 180–4.

**Henderson, Chas. F.,** and Horace V. McBurnie. 1943. Sampling technique for determining populations of the citrus red mite and its predators. U. S. Dept. of Agr. Cir. 671.

**Hough, W. S.,** D. W. Clancy, and H. N. Pollard. 1945. DDT and its effect on the Comstock mealybug and its parasites. JOUR. ECON. ENT. **38**(4): 422.

**Newcomer, E. J.,** and F. P. Dean. 1953. Control of woolly apple aphids in orchards sprayed with DDT. JOUR. ECON. ENT. **46**(1): 54.

**Ortega, J. C.** 1953. Systemic pesticides on walnut. Calif. Agr. **7**(10): 10.

**Steiner, L. F.,** C. H. Arnold, and S. A. Summerland. 1944. Laboratory and field tests of DDT for control of the codling moth. JOUR. ECON. ENT. **37**(1): 156.

# Termite Danger Zones in New York State and Their Use in Termite Prevention

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The distribution of the eastern subterranean termite *Reticulitermes flavipes* (Kollar) in the continental United States has been well presented by Banks & Snyder (1920), Light & Pickins (1934), and Snyder (1948). Emerson (1936) noted that the northern limit of this insect is between the 40° F. and 45° F. annual isothermal lines. Although these presentations serve well for the United States as a whole, a more definite delimitation is desirable in those states, such as New York, lying only in part within the northern limits of termite distribution.

Using well defined limits, statewide recommendations in such media as bulletins and building codes can be stipulated more adequately, the stringency of preventative measures being commensurate with the risk of termite attack. For example, in Section 301c of the Code Manual, New York State Building Construction Code (1951), applicable to one- and two-family dwellings, provisions are outlined for the prevention of damage by subterranean termites. The code has been adopted by approximately 100 communities throughout New York State. The question now arises as to how rigidly each community should enforce these provisions. A workable answer to this problem should encourage building contractors and prospective home owners to practice termite prevention in preference to less desirable control measures that may become necessary after the structure is in use.

As a possible solution, it is proposed that the State of New York be divided into four zones of relative termite hazard (Figure 1). These zones are based on the incidence of termite damage throughout the state as determined from personal inspections, from mail inquiries with which identifiable samples were submitted, and from records of other workers. Personal observations were made of 64 cases of termite damage as part of a more comprehensive survey in which 3551 structures have been inspected for the presence or absence of insect damage.

In New York State, termites have been collected in the following localities:

*Collections by author:* In zone I, Beacon, Bloomington, Brentwood, Brooklyn, Farmingdale, Forest Park, Highland Falls, Jackson Heights, Kingston, Larchmont, Mamaroneck, Newburgh, New Paltz, Oakdale Station, Pinelawn, Poughkeepsie, Rye, Scarsdale, Tarrytown, White Plains. In zone II, Albany, Binghamton, Glens Falls, Lake Hadley, Lake Luzerne, Lakemont, Newark, Oneonta, Rochester, Saratoga, Schenectady, Sodus Point.

*Inquiries:* In zone I, Bronxville, Brooklyn, Hempstead, Huntington Station, Kingston, Larchmont, Oyster Bay Cove, White Plains. In zone II, Albany Binghamton, Ithaca, Rochester, Schenectady, Scotia, Selkirk.

*Records of Dr. D. L. Collins*[2]*:* In zone I, Hastings-on-Hudson. In zone II, Colonie, New Salem.

*Records of Dr. P. J. Chapman*[3]*:* In zone II, Geneva, Lake Owasco (East side, ten miles south of Auburn), Penn-Yan, Waterloo.

*Previously compiled by Leonard* (1926): In zone I, Bergen Beach, Bronx Park, Brooklyn, Cold Springs Harbor, Floral Park, Karner, Long Island City, Mosholu, Mt. Vernon, New York City, Pinelawn, Port Richmond, Sea Cliff, Staten Island, White Plains. In zone II, Albany, Binghamton, Ithaca.

The proposed zones of relative termite danger are defined as follows:

*Zone I* is an area of high hazard, in which nearly every structure is in danger of termite attack. Included are Long Island and the greater part of counties along the Hudson River as far north as Kingston.

*Zone II* is an area of moderate termite hazard. Termites have been collected in this zone, but they are abundant only in small localized areas, while in adjacent areas they are very difficult to find. Included are the counties adjacent to the Hudson River from Kingston northward to Glens Falls and Lake Luzerne; the Finger Lakes region; and the areas near the Susquehanna and Delaware Rivers.

Both zones I and II, it should be noted, coincide closely with the Upper Austral bioclimatic zone mapped for New York State by Lintner (1895) after an outline by C. H. Merriam.

*Zone III* is an area of low termite haz-

[1] The writer is indebted to Drs. T. E. Snyder, R. B. Friend, N. Turner, D. L. Collins, P. J. Chapman, F. J. Czabator, and J. L. Krall for their helpful suggestions and criticisms of the manuscript.

[2] University of the State of New York, New York State Science Service. Personal communication, Jan. 19, 1954.

[3] New York State Agricultural Experiment Station. Mostly from collections by Mr. M. Bittman of Finger Lakes Exterminating Co. Personal communication, Jan. 5, 1954.



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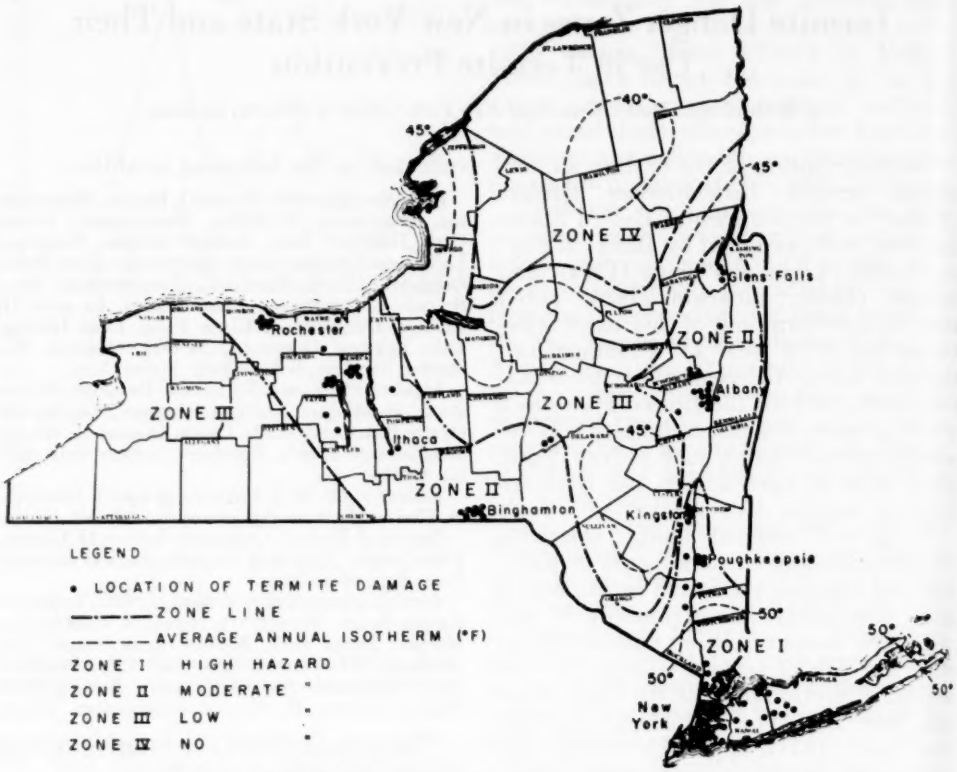


FIG. 1.—Map of New York State showing distribution of the eastern subterranean termite.

ard. No termites have been reported within this area. However, because of its proximity to zone II, and its similar climatic conditions, termites cannot be entirely discounted. It includes central New York and the counties west of the Finger Lakes region.

*Zone IV* is an area of no termite hazard. This zone is in the northern part of the state where the climate is not favorable to termites.

Having established these zones, the provisions for termite prevention can be presented more adequately. These are outlined in table 1, the need for each practice being indicated by an X in the column under each zone.

Emphasis on the first two provisions is warranted by mounting evidence in the northeastern United States that poor con-

**Table 1.—Termite prevention in buildings in New York State.**

| Recommended Practice | Zone I | Zone II | Zone III | Zone IV |
|---|---|---|---|---|
| Sound construction; masonry foundation, 18″ inside, 6″ outside minimum height | X | X | X | |
| Removal of wood debris from building site and foundation backfill. | X | X | X | |
| Chemical treatment of building site. | X | X | need determined by inspection | |
| Metal shield or concrete slab to cap foundation. | X | | | |

struction and failure to clear the site of wood debris are the principal causes of termite attacks in structures. Of the 64 cases inspected by the writer, at least 61 could be attributed to neglect of these precautions; the remaining three cases, all in zone I, being of doubtful origin. This is in accord with the findings of Turner *et al.* (1935, 1936, 1939), and Headlee (1937), that termite attack is generally induced by direct contact between the wood and the soil.

The installation of termite barriers of non-corrosive metal or reinforced concrete, in view of their high initial cost and the need to insure that they are properly constructed, would be very difficult to enforce as part of a building code. Perhaps their use should be optional. Evidence by Holway (1941), that the eastern subterranean termite builds its tubes generally downward and very rarely in an upward direction, suggests that termite damage would be negligible if poor design and careless construction could be eliminated in wooden structures. However, Holway (*op. cit.*, p. 390) also states that "concentration of population may be an important factor in judging what conditions favor upward tube-building by *Reticulitermes*." Furthermore, Dr. T. E. Snyder based on his 44 years' experience, doubts very much that *R. flavipes* usually builds tubes downward.[4] Until this important question of termite behavior under variable conditions of population density is clarified, a termite barrier to cap the foundations of wooden structures in zone I is recommended.

[4] Personal communication, Dec. 30, 1953.

## LITERATURE CITED


Banks, N., and T. E. Snyder. 1920. A revision of the nearctic termites. U. S. Nat. Mus. Bul. 108.

Emerson, A. E. 1936. Distribution of termites. Science 83(2157): 410–1.

Headlee, T. J. 1937. Experiences with the termite in New Jersey. JOUR. ECON. ENT. 30(2): 337–41.

Holway, R. T. 1941. Tube-building habits of the eastern subterranean termite. JOUR. ECON. ENT. 34(3): 389–94.

Leonard, M. D. 1926. A list of the insects of New York. Cornell Agr. Expt. Sta. Mem. 101.

Light, S. F., and A. L. Pickens. 1934. American subterranean termites, their classification and distribution. In Kofoid *et al.* 1934. Termites and termite control. Univ. Calif. Press, Berkeley. 150–6.

Lintner, J. A. 1895. *Crioceris asparagi* (Linn.) the asparagus beetle. Eleventh Rept. of the State Entomologist, Forty-ninth Rept. on the State Museum, Univ. of the State of N. Y. 177–81.

New York State. 1951. Code manual for the state building construction code. State Building Code Commission, New York, N. Y.

Snyder, T. E. 1948 (Rev.). Our enemy the termite. Comstock Pub. Co., Inc., Ithaca, N. Y.

Turner, N., J. F. Townsend, and M. P. Zappe. 1935. Observations on termite damage in Connecticut. Conn. Agr. Expt. Sta. Bul. 368: 241–5.

Turner, N., and M. P. Zappe. 1936. Termite damage in Connecticut. JOUR. ECON. ENT. 29 (1): 195–8

Turner, N., and J. F. Townsend. 1939. Control of termites in buildings. Conn. Agr. Expt. Sta. Cir. 134

# The Toxicity to House Flies of Allethrin Analogs in Combination with Piperonyl Butoxide Analogs

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Since the advent of allethrin as one of the newer synthetic insecticides, rather extensive studies have been made to determine the effect of alterations in the structure of the allethrin molecule on its insecticidal activity. Early work by Gersdorff (1949) showed that esterification of the cyclopentenolone substituted with a 2-butenyl side chain resulted in an ester about one-fifth as toxic as the ester from the alcohol with an allyl substituent group. Gersdorff & Mitlin (1951) also found that the introduction of chlorine in these side chains gave compounds much less toxic than allethrin. In Japan, Inoue *et al.* (1951) evaluated a number of the analogs of allethrin, including the methyl, ethyl, and propyl, and found that they were generally less effective than allethrin. Japanese workers also studied the synthesis and activity of the furfuryl analog of allethrin, referred to as "Furethrin," and Gersdorff & Mitlin (1952) reported the Japanese material, as well as some prepared in this country, to be less effective than allethrin in tests on house flies.

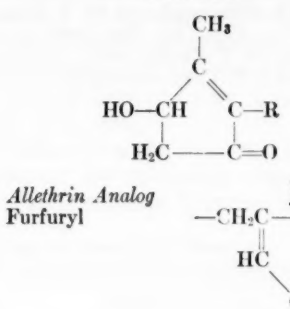
In addition to this work on variations of the toxicant structure, the activity of allethrin in combination with known pyrethrum synergists has been determined and found to be of a lower order than similar mixtures of the synergists with pyrethrins (Jones *et al.* 1950). Among these materials evaluated as synergists for allethrin, piperonyl butoxide has been shown to be one of the most active (Gersdorff *et al.* 1951); however, no studies have been reported on the synergistic effectiveness of analogs of piperonyl butoxide with allethrin or its analogs. Wachs *et al.* (1950) did evaluate six compounds structurally related to piperonyl butoxide in combinations with pyrethrins on house flies, and Gersdorff *et al.* (1952) showed that another related compound synergized both pyrethrum and allethrin, but to a lesser degree with the latter toxicant. Turner (1953) also worked with piperonyl butoxide combined with allethrin and certain analogs of piperonyl butoxide in combination with some of the organic and inorganic insecticides; however, it should be noted that his tests were made on the large milkweed bug, *Oncopeltus fasciatus* (Dall.) by the injection method, and in general did not agree with previous data obtained in space spray tests on house flies.

The tests described in this paper were made to determine the effectiveness of sprays containing the furfuryl, thenyl and benzyl analogs of allethrin alone and in combination with piperonyl butoxide and seven of its analogs.

MATERIALS.—The three analogs of allethrin were prepared by esterification of substituted cyclopentenolones (alcohol portion of the molecule) with synthetic (dl) *cis- trans* chrysanthemum monocarboxylic acid. The substituted cyclopentenolones are represented by the general formula I, in which R represents different side-chains ($R = -CH_2CH=CH_2$ for allethrin).

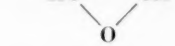
For evaluation as synergists with these toxicants, seven methylenedioxyphenyl

*Formula I*

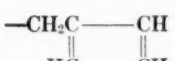


*Allethrin Analog*

Furfuryl



Thenyl



Benzyl

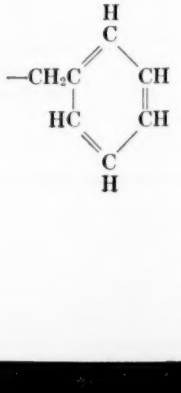
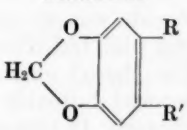


**Table 1.—Toxicity to house flies of sprays containing the furfuryl, thenyl, and benzyl analogs of allethrin.**

| Concentration (mg./100 ml.) | | | | | |
|---|---|---|---|---|---|
| Allethrin | Allethrin Analog | No. Tests | Mortality in 1 Day (Per Cent) | LC 50 (mg./100 ml.) | Relative Effectiveness at LC 50 (Allethrin = 1.00) |
| | | *Series 1—Furfuryl Analog* | | | |
| 200 | — | 2 | 34 | | |
| 300 | — | 2 | 62 | | |
| 400 | — | 2 | 75 | 260 | — |
| — | 300 | 2 | 38 | | |
| — | 400 | 2 | 48 | | |
| — | 600 | 2 | 62 | 450 | 0.58 |
| | | *Series 2—Thenyl Analog* | | | |
| 200 | — | 4 | 38 | | |
| 300 | — | 4 | 55 | | |
| 400 | — | 4 | 75 | 255 | — |
| — | 400 | 4 | 31 | | |
| — | 600 | 4 | 52 | | |
| — | 800 | 4 | 64 | 590 | 0.43 |
| | | *Series 3—Benzyl Analog* | | | |
| 300 | — | 8 | 60 | | |
| 400 | — | 8 | 78 | | |
| 600 | — | 8 | 93 | 260 | — |
| — | 300 | 8 | 24 | | |
| — | 400 | 8 | 34 | | |
| — | 600 | 8 | 52 | | |
| — | 1200 | 8 | 85 | 550 | 0.47 |

derivatives, which are analogs of piperonyl butoxide, were prepared. They are represented by the general formula II, in which R and R′ represent various groups (R = $-CH_2CH_2CH_3$ and R′ = $-Ch_2OCH_2CH_2OCH_2CH_2OC_4H_9$ for piperonyl butoxide). Thus there were eight materials, including piperonyl butoxide, available for comparison of synergistic activity when formulated in combination with allethrin and the three allethrin analogs.

*Formula II*



| *Piperonyl Butoxide Analog* | *R* | *R′* |
|---|---|---|
| a | $-CH_2CH_2CH_3$ | $-CH_2OCH_2CH_2OCH_2CH_2OC_2H_5$ |
| b | $-CH_2CH_2CH_3$ | $-CH_2OCH_2CH_2OC_4H_9$ |
| c | $-CH_2CH_2CH_3$ | $-CH_2OCH_2CH_2OCH_2CH_2OCH_3$ |
| d | $-CH_2CH_2CH_3$ | $-CH_2OCH_2CH_2OCH_2C_6H_5$ |
| e | $-CHCH_2CH_3$ <br> $\vert$ <br> $OCH_2CH_2OCH_2CH_2OC_4H_9$ | H |
| f | $-CH_2CH_2CH_2OCH_2CH_2OC_4H_9$ | H |
| g | $-CH_2OCH_2CH_2OC_6H_5$ | H |

Sprays containing allethrin and the furfuryl, thenyl and benzyl analogs of allethrin alone, as well as combined with piperonyl butoxide and seven of its analogs at a 1 to 10 ratio, were prepared by dissolving these materials in refined kerosene. The allethrin used as a standard in this study was a technical grade material analyzing 79.8 per cent pure allethrin by the ethylenediamine method, as outlined by Hogsett, *et al.* (1953). Formulations of the allethrin sprays were made on the basis of the technical grade material without correcting for purity. The three allethrin analogs also were formulated without correction for purity.

METHODS.—The tests were made by the turntable method on 3-day-old house flies, *Musca domestica* L., reared by standard procedure. Approximately 100 house flies were used per test. Concentrations of allethrin and its three analogs alone and in combination with piperonyl butoxide and its seven analogs which would give mortalities in the range including or approaching 50 per cent were determined in a preliminary study. All of the sprays then were tested at three different concentrations to give dosage-mortality curves in-

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**Table 2.—Toxicity to house flies of sprays containing the furfuryl, thenyl and benzyl analogs of allethrin in combination with piperonyl butoxide.**

| Concentration (mg./100 ml.) | | | | | | |
|---|---|---|---|---|---|---|
| Allethrin | Allethrin Analog | Piperonyl Butoxide | No. Tests | Mortality in 1 Day (Per Cent) | LC 50 (mg./100 ml.) | Relative Effectiveness at LC50 (Allethrin+Butoxide=1.00) |
| | | | *Series 1—Furfuryl Analog* | | | |
| 60 | — | 600 | 4 | 36 | | |
| 80 | — | 800 | 4 | 70 | | |
| 100 | — | 1000 | 4 | 85 | 68+680 | — |
| — | 50 | 500 | 4 | 59 | | |
| — | 60 | 600 | 4 | 72 | | |
| — | 80 | 800 | 4 | 85 | 44+440 | 1.55 |
| | | | *Thenyl Analog* | | | |
| — | 50 | 500 | 4 | 42 | | |
| — | 60 | 600 | 4 | 69 | | |
| — | 80 | 800 | 4 | 84 | 53+530 | 1.28 |
| | | | *Series 2—Benzyl Analog* | | | |
| 50 | — | 500 | 3 | 29 | | |
| 60 | — | 600 | 3 | 59 | | |
| 70 | — | 700 | 3 | 79 | | |
| 90 | — | 900 | 3 | 91 | 58+580 | — |
| — | 50 | 500 | 3 | 33 | | |
| — | 60 | 600 | 3 | 55 | | |
| — | 70 | 700 | 3 | 72 | | |
| — | 90 | 900 | 3 | 88 | 58+580 | 1.00 |

tersecting the 50 per cent mortality level.

The 1-day mortality results were entered on log-probability paper and the LC50 concentration for each solution was estimated from the resulting graphically fitted straight lines. Since the large number of compounds and various concentrations available for evaluation could not be tested simultaneously, allethrin alone or in combination with a given synergistic material was used as a standard in each series of tests. A figure representing the relative effectiveness of each of the sprays was obtained from the ratio of the LC50 of the allethrin standard to the LC50 value of the test solutions, and this relative effectiveness value served as a means of expressing the activity of each of the allethrin analogs in relation to that of allethrin alone as well as allethrin in combination with the synergistic materials.

Results.—The results of tests of the furfuryl, thenyl and benzyl allethrin analogs alone are given in Table 1. Comparisons of relative effectiveness values show that the furfuryl analog alone had 58 per cent of the effectiveness of allethrin, while the thenyl and benzyl analogs were less than one-half as toxic. (Fig. 1). Although the relative effectiveness of the furfuryl analog when compared with technical allethrin is somewhat higher than the value arrived at by Gersdorff in similar tests with nearly pure allethrin (1952), the general conclusion that this analog alone is definitely less effective than allethrin may be made in both instances.

Tests of sprays containing the three allethrin analogs in combination with piperonyl butoxide at a 1 to 10 ratio demonstrated marked synergistic activity for these mixtures (Table 2). The relative effectiveness values showed that the furfuryl analog of allethrin combined with piperonyl butoxide was $1\frac{1}{2}$ times as effective as allethrin plus butoxide. The effectiveness of the thenyl analog of allethrin with piperonyl butoxide was shown to be approximately $1\frac{1}{4}$ times that of the standard allethrin-piperonyl butoxide mixture and the benzyl analog, when combined with butoxide, was equal to the standard mixture (Fig. 1).

Sprays containing the three analogs of allethrin in combination with each of the seven piperonyl butoxide analogs were evaluated in comparison with mixtures of allethrin with the seven analogs. All combinations were made at a ratio of one part of toxicant to 10 parts of butoxide

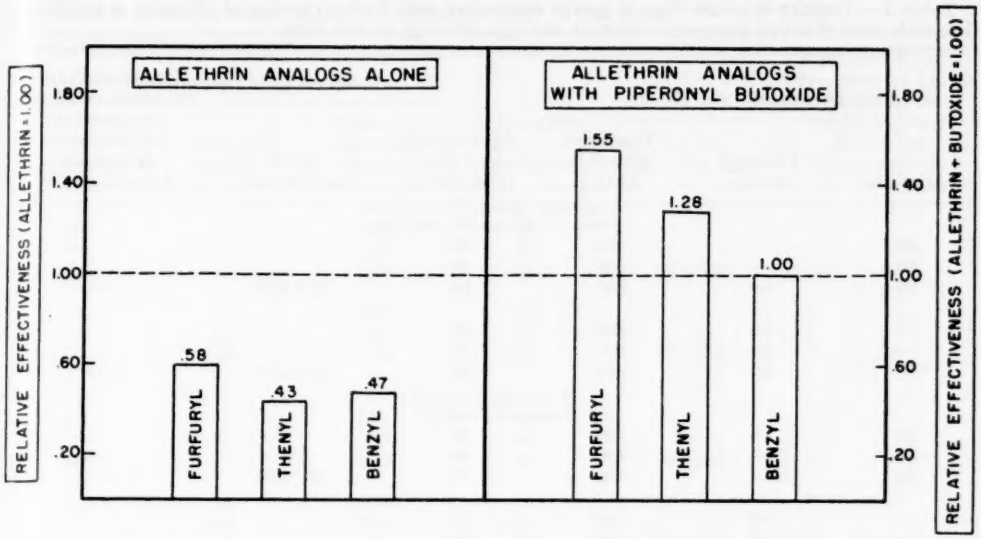


FIG. 1.—Relative effectiveness of allethrin and the furfuryl, thenyl, and benzyl analogs of allethrin alone and when combined with piperonyl butoxide.

analog. The results of these tests are shown in tables 3 to 5 and figures 2 to 4. Since preliminary tests of the piperonyl butoxide analogs at concentrations of 2 per cent in base oil showed that they are relatively ineffective when used alone, a comparison of the estimated LC50 concentrations listed in table 1 with those of tables 3 to 5 indicate synergistic activity for all mixtures.

The furfuryl analog of allethrin, when tested in combination with each of the analogs of piperonyl butoxide, gave relative effectiveness values which showed it to be equal or superior to allethrin with each of these analogs except g (Table 3 and Fig. 2). In addition, it is apparent from the degree of difference in relative effectiveness between the two toxicants, when used in combination with each an-

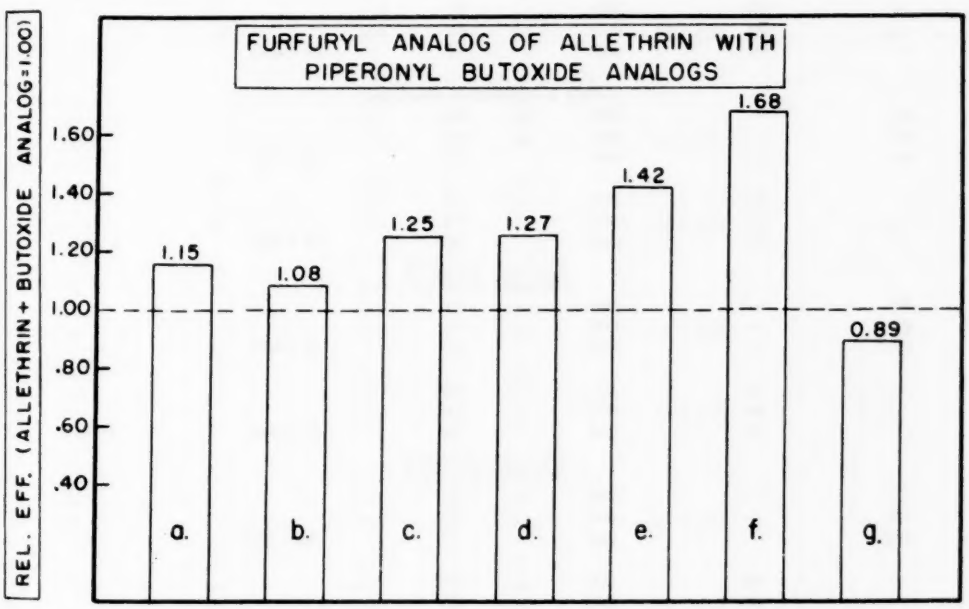


FIG. 2.—Relative effectiveness of allethrin and the furfuryl analog of allethrin when combined with analogs of piperonyl butoxide.

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**Table 3.—Toxicity to house flies of sprays containing with furfuryl analog of allethrin in combination with each of seven piperonyl butoxide analogs. Average of two tests.**

| Concentration (mg./100 ml.) | | | Mortality in 1 Day (Per Cent) | LC 50 (mg./100 ml.) | Relative Effectiveness at LC 50 (Allethrin + Piperonyl Butoxide Analog = 1.00) |
|---|---|---|---|---|---|
| Allethrin | Furfuryl Analog | Piperonyl Butoxide Analog | | | |
| | | | *Series 1—Butoxide Analog a* | | |
| 50 | — | 500 | 22 | | |
| 60 | — | 600 | 49 | | |
| 80 | — | 800 | 84 | 61+610 | — |
| — | 50 | 500 | 46 | | |
| — | 60 | 600 | 58 | | |
| — | 80 | 800 | 90 | 53+530 | 1.15 |
| | | | *Butoxide Analog b* | | |
| 50 | — | 500 | 26 | | |
| 60 | — | 600 | 26 | | |
| 80 | — | 800 | 78 | 65+650 | — |
| — | 50 | 500 | 29 | | |
| — | 60 | 600 | 46 | | |
| — | 80 | 800 | 83 | 60+600 | 1.08 |
| | | | *Butoxide Analog c* | | |
| 50 | — | 500 | 50 | | |
| 60 | — | 600 | 68 | | |
| 80 | — | 800 | 92 | 50+500 | — |
| — | 40 | 400 | 45 | | |
| — | 50 | 500 | 80 | | |
| — | 60 | 600 | 86 | 40+400 | 1.25 |
| | | | *Butoxide Analog d* | | |
| 50 | — | 500 | 36 | | |
| 60 | — | 600 | 38 | | |
| 80 | — | 800 | 81 | 61+610 | — |
| — | 50 | 500 | 51 | | |
| — | 60 | 600 | 68 | | |
| — | 80 | 800 | 82 | 48+480 | 1.27 |
| | | | *Series 2—Butoxide Analog e* | | |
| 50 | — | 500 | 44 | | |
| 60 | — | 600 | 58 | | |
| 80 | — | 800 | 88 | 54+540 | — |
| — | 40 | 400 | 58 | | |
| — | 50 | 500 | 74 | | |
| — | 60 | 600 | 88 | 38+380 | 1.42 |
| | | | *Butoxide Analog f* | | |
| 50 | — | 500 | 31 | | |
| 60 | — | 600 | 64 | | |
| 80 | — | 800 | 80 | 57+570 | — |
| — | 50 | 500 | 66 | | |
| — | 60 | 600 | 76 | | |
| — | 70 | 700 | 78 | 34+340 | 1.68 |
| | | | *Butoxide Analog g* | | |
| 70 | — | 700 | 64 | | |
| 80 | — | 800 | 76 | | |
| 90 | — | 900 | 79 | 56+560 | — |
| — | 50 | 500 | 36 | | |
| — | 60 | 600 | 50 | | |
| — | 80 | 800 | 63 | 63+630 | 0.89 |

**Table 4.—Toxicity to house flies of sprays containing the thenyl analog of allethrin in combination with each of seven piperonyl butoxide analogs. Average of two tests.**

| Concentration (Mg./100 Ml.) | | | | | Relative Effectiveness at LC 50 (Allethrin + Piperonyl Butoxide Analog = 1.00) |
|---|---|---|---|---|---|
| Allethrin | Thenyl Analog | Piperonyl Butoxide Analog | Mortality in 1 Day (Per Cent) | LC 50 (Mg./100 Ml.) | |
| | | | *Series 1—Butoxide Analog a* | | |
| 60 | — | 600 | 54 | | |
| 70 | — | 700 | 75 | | |
| 80 | — | 800 | 75 | 54+540 | — |
| — | 40 | 400 | 26 | | |
| — | 50 | 500 | 38 | | |
| — | 60 | 600 | 72 | 52+520 | 1.04 |
| | | | *Butoxide Analog b* | | |
| 60 | — | 600 | 41 | | |
| 70 | — | 700 | 52 | | |
| 80 | — | 800 | 62 | 68+680 | — |
| — | 40 | 400 | 10 | | |
| — | 50 | 500 | 24 | | |
| — | 60 | 600 | 42 | 64+640 | 1.06 |
| | | | *Butoxide Analog c* | | |
| 40 | — | 400 | 15 | | |
| 50 | — | 500 | 49 | | |
| 70 | — | 700 | 87 | 52+520 | — |
| — | 30 | 300 | 28 | | |
| — | 40 | 400 | 56 | | |
| — | 50 | 500 | 74 | 38+380 | 1.37 |
| | | | *Butoxide Analog d* | | |
| 60 | — | 600 | 42 | | |
| 70 | — | 700 | 74 | | |
| 80 | — | 800 | 69 | 61+610 | — |
| — | 40 | 400 | 26 | | |
| — | 50 | 500 | 41 | | |
| — | 60 | 600 | 50 | 59+590 | 1.03 |
| | | | *Series 2—Butoxide Analog e* | | |
| 50 | — | 500 | 57 | | |
| 60 | — | 600 | 80 | | |
| 80 | — | 800 | 96 | 47+470 | — |
| — | 40 | 400 | 64 | | |
| — | 50 | 500 | 92 | | |
| — | 60 | 600 | 92 | 33+330 | 1.42 |
| | | | *Butoxide Analog f* | | |
| 50 | — | 500 | 46 | | |
| 60 | — | 600 | 62 | | |
| 80 | — | 800 | 78 | 52+520 | — |
| — | 50 | 500 | 64 | | |
| — | 60 | 600 | 82 | | |
| — | 80 | 800 | 85 | 36+360 | 1.44 |
| | | | *Butoxide Analog g* | | |
| 50 | — | 500 | 32 | | |
| 60 | — | 600 | 57 | | |
| 80 | — | 800 | 77 | 59+590 | — |
| — | 50 | 500 | 27 | | |
| — | 60 | 600 | 49 | | |
| — | 80 | 800 | 64 | 65+650 | 0.91 |

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**Table 5.—Toxicity to house flies of sprays containing the benzyl analog of allethrin in combination with each of seven piperonyl butoxide analogs. Average of two tests.**

| Concentration (Mg./100 Ml.) | | | Mortality in 1 Day (Per Cent) | LC 50 (Mg./100 Ml.) | Relative Effectiveness at LC 50 (Allethrin + Piperonyl Butoxide Analog = 1.00) |
|---|---|---|---|---|---|
| Allethrin | Benzyl Analog | Piperonyl Butoxide Analog | | | |
| | | *Series 1—Butoxide Analog a* | | | |
| 50 | — | 500 | 24 | | |
| 60 | — | 600 | 48 | | |
| 80 | — | 800 | 62 | 66+660 | — |
| — | 50 | 500 | 24 | | |
| — | 60 | 600 | 26 | | |
| — | 80 | 800 | 44 | 96+960 | 0.69 |
| | | *Butoxide Analog b* | | | |
| 50 | — | 500 | 20 | | |
| 60 | — | 600 | 32 | | |
| 80 | — | 800 | 53 | 77+770 | — |
| — | 50 | 500 | 8 | | |
| — | 60 | 600 | 23 | | |
| — | 80 | 800 | 40 | 85+850 | 0.91 |
| | | *Butoxide Analog d* | | | |
| 60 | — | 600 | 40 | | |
| 70 | — | 700 | 50 | | |
| 80 | — | 800 | 64 | 68+680 | — |
| — | 60 | 600 | 24 | | |
| — | 70 | 700 | 42 | | |
| — | 80 | 800 | 59 | 75+750 | 0.91 |
| | | *Series 2—Butoxide Analog c* | | | |
| 50 | — | 500 | 58 | | |
| 60 | — | 600 | 78 | | |
| 80 | — | 800 | 84 | 42+420 | — |
| — | 50 | 500 | 36 | | |
| — | 60 | 600 | 62 | | |
| — | 80 | 800 | 76 | 56+560 | 0.75 |
| | | *Butoxide Analog e* | | | |
| 50 | — | 500 | 56 | | |
| 60 | — | 600 | 79 | | |
| 80 | — | 800 | 90 | 46+460 | — |
| — | 50 | 500 | 58 | | |
| — | 60 | 600 | 78 | | |
| — | 80 | 800 | 88 | 44+440 | 1.05 |
| | | *Butoxide Analog f* | | | |
| 50 | — | 500 | 47 | | |
| 60 | — | 600 | 65 | | |
| 80 | — | 800 | 89 | 52+520 | — |
| — | 50 | 500 | 32 | | |
| — | 60 | 600 | 45 | | |
| — | 80 | 800 | 86 | 59+590 | 0.88 |
| | | *Butoxide Analog g* | | | |
| 50 | — | 500 | 40 | | |
| 60 | — | 600 | 57 | | |
| 80 | — | 800 | 84 | 55+550 | — |
| — | 50 | 500 | 20 | | |
| — | 60 | 600 | 32 | | |
| — | 80 | 800 | 61 | 72+720 | 0.76 |

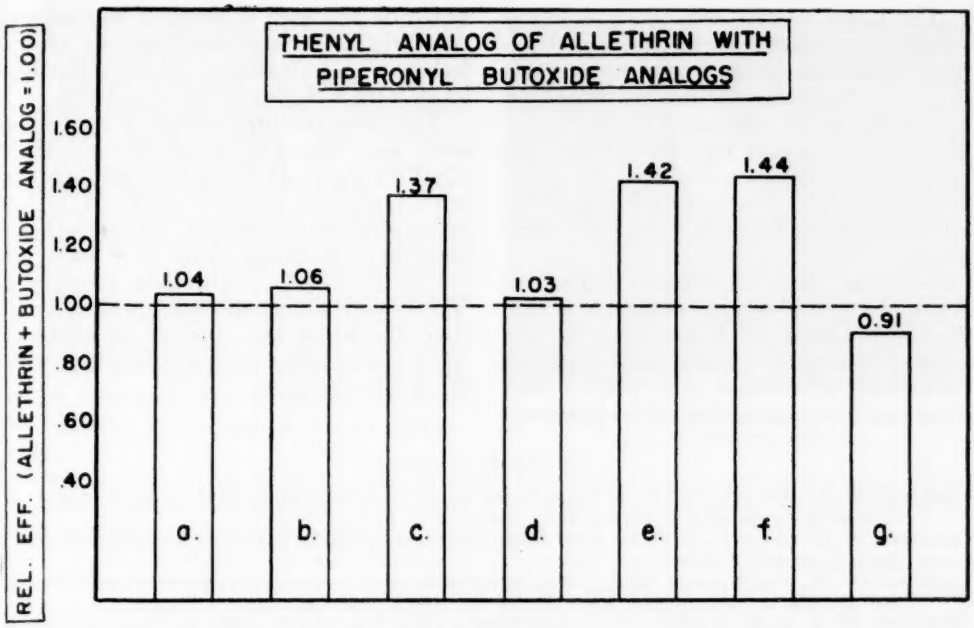


FIG. 3.—Relative effectiveness of allethrin and the thenyl analog of allethrin when combined with analogs of piperonyl butoxide.

alog of butoxide, that the furfuryl analog showed the greatest increase over allethrin in combination with analog f. Similarly, the thenyl analog proved to be about equal to or more effective than allethrin in combination with all of the piperonyl butoxide analogs except g and also showed its greatest superiority when used in combination with analog f (Table 4 and Fig. 3).

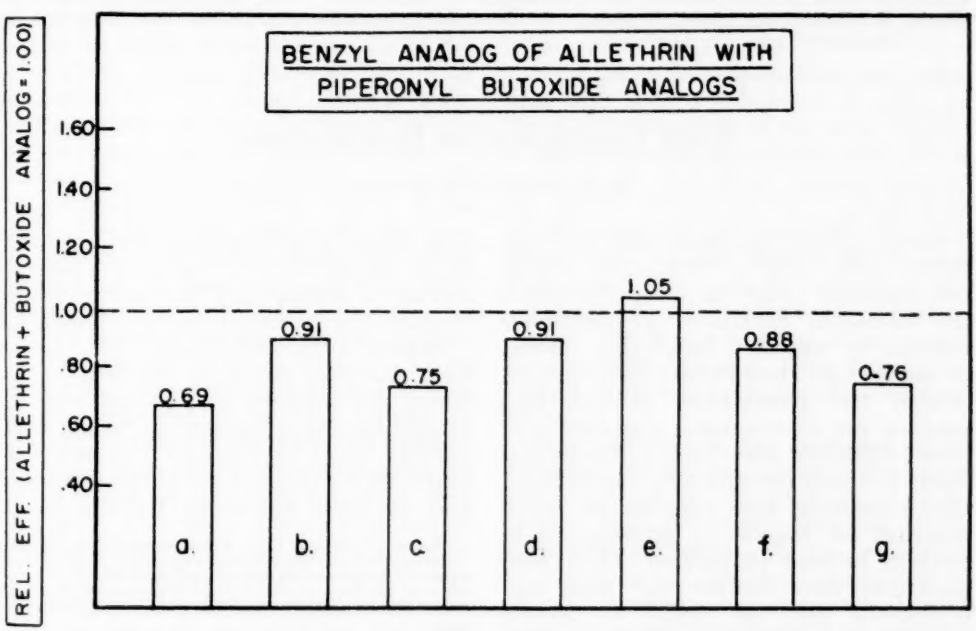


FIG. 4.—Relative effectiveness of allethrin and the benzyl analog of allethrin when combined with analogs of piperonyl butoxide.

The lower relative effectiveness values found in combinations of the benzyl analog of allethrin with piperonyl butoxide also occurred in tests of this material with six of the seven piperonyl butoxide analogs (Table 5 and Fig. 4). In only one instance, the combination with butoxide analog e, was the benzyl analog approximately equal to allethrin with this synergist.

SUMMARY AND CONCLUSIONS.—The furfuryl, thenyl and benzyl analogs of allethrin were tested on house flies by the turntable method to determine their effectiveness in oil-base sprays when used alone or in combination with piperonyl butoxide and each of seven of its analogs. Allethrin alone and combinations of allethrin with butoxide or its respective analogs were included as the standards.

The three allethrin analogs when tested alone were shown to be less effective than allethrin alone. However, in combination with piperonyl butoxide and six of its seven analogs the furfuryl and thenyl analogs were generally equal to or more effective than allethrin with these synergists. The benzyl analog showed lower activity than the other two analogs of allethrin when tested alone or in combination with the same synergists.

## LITERATURE CITED

**Gersdorff, W. A.** 1949. The toxicity to house flies of some synthetic compounds of the pyrethrum type in relation to chemical structure. JOUR. ECON. ENT. **42**(3): 532–7.

**Gersdorff, W. A.**, and Norman Mitlin. 1951. Relative toxicity of allethrin analogs to house flies. JOUR. ECON. ENT. **44**(1): 70–3.

**Gersdorff, W. A.**, and Norman Mitlin. 1952. Relative toxicity of furethrin, its natural acid isomer, and pyrethrins to house flies. JOUR. ECON. ENT. **45**(5): 849–50.

**Gersdorff, W. A.**, R. H. Nelson, and Norman Mitlin. 1951. The relative effect of several pyrethrum synergists in fly sprays containing allethrin. JOUR. ECON. ENT. **44**(6): 921–7.

**Gersdorff, W. A.**, R. H. Nelson, and Norman Mitlin. 1952. Sulfoxide and 3,4-Methylenedioxybenzyl n-Propyl Ether in pyrethrum and allethrin mixtures as house fly sprays. JOUR. ECON. ENT. **45**(6): 905–8.

**Hogsett, J. N.**, H. W. Kacy, and J. B. Johnson. 1953. Analysis of Commercial Allethrin. Anal. Chem. **25**(8): 1207–11.

**Inoue, Y.**, Y. Katsuda, A. Nishimura, K. Kitagawa, and M. Ohno. 1951. Studies on the synthetic pyrethrins III. Insecticidal effect of synthetic pyrethroids. Botyu-Kagaka **16**: 153–7.

**Jones, H. A.**, H. O. Schroeder, and H. H. Incho. 1950. Allethrin with Synergists. Soap and Sanitary Chemicals **XXVI**: C.S.M.A. (1): 63–6.

**Turner, N.** 1953. Methylenedioxyphenyl synergists for insecticides. Conn. Agr. Expt. Sta. Bul. 570.

**Wachs, H.**, H. A. Jones, and L. W. Bass. 1950. New safe insecticides. Amer. Chem. Soc. Advances in Chemistry Series No. 1: 43–8.

# Field Domiciles for Bumblebees

R. E. FYE and J. T. MEDLER[1]

Sladen (1912), Lindhard (1912), Frison (1918, 1923,[2] 1927), Plath (1923, 1934) and Hasselrot (1952) have reported upon the successful initiation of bumblebee colonies by confining bumblebee queens in the spring. Their results have demonstrated the possibilities of obtaining colonies for experimental purposes and have established some basic requirements. Their methods are probably too tedious, time-consuming and exacting to prove practical for bumblebee propagation in relation to seed production. Most seed producers have neither the time and equipment nor the desire to handle bumblebees in the spring. Rather extensive experiments have been made with field domiciles in Wisconsin, because it appears desirable to develop a practical method of propagating bumblebees which requires a minimum of time and handling.

Sladen (1912) and Frison (1923,[2] 1926) used domiciles placed in the field in the spring and supplied with rodent nests to attract the searching queens. Sladen used various types of holes in the soil, but found that rodents invaded the domiciles and destroyed the nests. He also found

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[2] Frison, T. H. 1923. Biological studies of the Bremidae, or bumblebees with special reference to the species occurring in Illinois. Unpublished thesis Univ. of Illinois.

that ants invaded the nests, and, by stealing eggs and provisions in the absence of the queen, were able to demoralize the queens sufficiently to cause abandonment. Sladen's main problem was excessive moisture, which caused the queens to abandon the newly-founded nests.

Frison utilized metal containers and wooden boxes as domiciles either buried or placed in logs and similar situations. He attained as high as 67 per cent acceptance of the domiciles. He experienced little trouble with rodent invasion but lost a number of domiciles through theft. His main difficulty was excessive moisture, particularly in the case of the metal domiciles.

PROCEDURE.—One hundred and thirty wooden boxes approximately $\frac{1}{5}$ to $\frac{1}{4}$ cubic foot in volume were constructed of 1-inch stock lumber and the majority with a bottom of 2-inch stock. Lids were constructed of 1-inch lumber and covered with roofing paper. A $1\frac{1}{4}$-inch hole was bored in the side of each box. Three similar boxes of $\frac{1}{8}$ cubic foot volume were built to be placed several feet above the ground on buildings.

One-inch holes were bored in the sides of seven flower pots and lids for the pots were made with 1-inch lumber covered with roofing paper.

Subterranean domiciles were placed about 12 inches below the surface of the ground. A wooden cover was filled with excavated sod and placed over the domiciles as shown in figure 1. Domiciles were metal cans of the type shown in figure 1, or clay tiles 8 inches in diameter and 1 foot long buried upright in the bottom of the hole. The tiles were filled with sand, except for upper 4 inches. A short length of rubber garden hose was used for an entrance tunnel.

The wooden box domiciles were placed on the ground in fence rows, orchards, windbreak strips, stump piles and various other situations where they might be readily located by the searching bumblebee queens in the spring. The domiciles were placed on several farms in Bayfield County, Wisconsin, during the period August 15 to September 15, 1952.

Each of the boxes and flower pots was partially filled with flax straw, which was roughed up a bit to bring out the fiber, and a handful of mixed grain was included to encourage the entrance of mice. A 4 to 7-pound rock was placed on each lid to prevent the entry of invaders such as skunks.

FIG. 1.—A metal can domicile located in a subterranean position.

In late April, 1953, two metal-can-type subterranean domiciles and 18 roofing paper cones made from 1-foot circles of roofing paper were placed in the field. Also in late April mouse nests or felt rug matting were placed in those boxes in which field mice had not constructed nests and in the subterranean domiciles. The mice were then excluded from the wooden domiciles on the ground by covering the entrance holes with a 2-inch square metal plate which contained a $\frac{5}{8}$ inch diameter hole. A typical wooden domicile is shown in figure 2.

RESULTS.—Acceptance by the mice, ants and bees is tabulated in table 1. Sixty-seven per cent of the total number of domiciles were occupied by mice, 27 per cent by ants, and 34 per cent by bumblebee queens. Domiciles were accepted by *Bombus rufocinctus* Cress., *B. separatus* Cress., *B. borealis* Kirby, *B. fervidus* Fabr., and *B. vagans* F. Sm. Generally speaking, the wooden boxes were well accepted. The flower pots and subterranean tiles in dry locations were readily accepted, but those in wetter areas were not occupied.

DISCUSSION.—At the initiation of the experiment it was hoped that a method of attracting queens to artificial domicles would prove sufficiently practical to become a useful practice in the production of legume seed. Although encourging results were obtained as shown above, it is not believed that the method has yet been fully developed. The native bumblebee population in 1953 was rather low as a

FIG. 2.—A wooden box domicile located in a stump pile.

consequence of a series of wet seasons. If more searching queens had been available a higher per cent of acceptance probably would have been shown. No correlation of bumblebee populations and seed yields was attempted in these experiments.

The wooden boxes in various situations at the ground surface and above solved several problems encountered by Sladen and Frison. Probably the most important of these was moisture control. Although 1953 was a rather wet season in northern Wisconsin, excessive moisture in the wooden domiciles was not a problem. In many cases the bottoms of the boxes were wet, but the mice's nests had sufficient material to keep the bee comb from getting too damp.

The greatest difficulty experienced with the subterranean domiciles was that of moisture. The excessively wet season coupled with the poorly drained clay soil made eight out of 10 of the tile domiciles uninhabitable. The colonies which were initiated in two of the tiles and the two metal models were at well drained sites. Some moisture collected on the internal wall of the metal domiciles but it was insufficient to cause trouble.

The half-buried flower pots became too moist and were probably unattractive to the searching queens for that reason. It is believed that moisture in the pots might be minimized by not burying the pots so deep and raising the floor level of the domicile above the surface of the ground by filling the pot with sand or light soil.

There was a complete absence of nests in the roofing paper cones. The cones may have been poorly placed or lacking in some factor the bees required. The black surface may have absorbed sufficient heat to make them excessively warm.

It is desirable to have something near the domicile to attract the searching queens' attention as noted by Frison. Domiciles placed near fence posts, rocks, trees and stumps and similar objects were occupied more frequently than those in the open. Although the domiciles are somewhat of an attraction themselves when placed in the grass with the weighting rock on the lid readily visible to the bees, it appears advisable to place some attractive object near the domicile to draw the searching queens' attention.

Research has shown that certain Wisconsin species prefer subterranean nesting sites. Among these are *Bombus terricola* Kirby and *B. ternarius* Say, two common species in northern Wisconsin which failed to nest in the surface domiciles. Since *B. terricola* is an exceptionally fine pollinator of legumes, particularly alfalfa, a method of domiciling this species is highly desirable. With the exception of *B. rufocinctus* the species utilizing the domiciles were exceptionally good pollinators of red clover and other seed legumes. *B. rufocinctus* seems to have a preference for floral hosts other than legumes, although at times it may appear in large numbers on white clover.

Ants, which Sladen found a problem, appeared in about 27 per cent of the domiciles in use. However, only one abandoned colony could be blamed on these insects. In that case a large colony of the ants took over the box and apparently were able to discourgage the queen sufficiently to cause abandonment. One other box with an abandoned bumblebee comb had both ants and a wasp nest present, but it is suspected that the wasps forced the eviction of the bee tenant. In general, when bee and ant colonies occurred in the box the two colonies each went their own way without interfering in one another's affairs although occasionally ants were noted stealing nectar from the bee's honeypot when the queen was out of the nest. Several experiments indicated that a band of dieldrin about the bottom of the box controlled the ants.

Mice presented a problem for they were occasionally found in the domiciles in spite of the metal plates with $\frac{5}{8}$ inch holes. The mice were particularly aggressive in their entrance late in the season. Eleven field

**Table 1.—Domicile acceptance by mice, ants, and bumblebees.**

| Location | Domicile Type | Occupants | | | | Species of Bombus | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | Mice | Ants | Bumblebees | *rufocinctus* | *separatus* | *borealis* | *fervidus* | *vagans* | Unidentified |
| Orchard | | | | | | | | | | | |
| At base of apple tree | Box | 8 | 8 | 4 | 3 | | | 3 | | | |
| | Flower pot | 1 | 0 | 0 | 0 | | | | | | |
| At base of plum tree | Box | 3 | 3 | 0 | 3 | 1 | 1 | 1 | | | |
| At base of cherry tree | Box | 2 | 2 | 1 | 0 | | | | | | |
| Beside stump | Flower pot | 1 | 1 | 1 | 0 | | | | | | |
| In grass | Flower pot | 1 | 0 | 0 | 0 | | | | | | |
| | Roofing paper cone | 6 | 0 | 2 | 0 | | | | | | |
| Totals | | 22 | 14 | 8 | 6 | 1 | 1 | 4 | 0 | 0 | 0 |
| Fence Rows | | | | | | | | | | | |
| Under brace posts | Box | 4 | 4 | 1 | 2 | | | 1 | 1 | | |
| At bases of posts | Box | 32 | 29 | 11 | 15 | 5 | | 4 | 3 | 2 | 1 |
| Beside rocks | Box | 3 | 3 | 0 | 1 | | | 1 | | | |
| | Subterranean tile | 2 | 0 | 0 | 0 | | | | | | |
| In grass and weeds | Box | 19 | 19 | 7 | 9 | 3 | 1 | 3 | 1 | | 1 |
| | Subterranean tile | 1 | 0 | 0 | 0 | | | | | | |
| In hazelbrush and grass | Box | 2 | 1 | 0 | 0 | | | | | | |
| In rock piles | Box | 2 | 2 | 0 | 1 | | | 1 | | | |
| Totals | | 65 | 58 | 19 | 28 | 8 | 1 | 10 | 5 | 2 | 2 |
| Stumps | | | | | | | | | | | |
| Piles in open fields | Box | 13 | 10 | 2 | 7 | 1 | | 3 | 3 | | |
| Beside individual stumps | Box | 6 | 4 | 1 | 1 | 1 | | | | | |
| | Subterranean tile | 1 | 0 | 0 | 0 | | | | | | |
| Totals | | 20 | 14 | 3 | 8 | 2 | | 3 | 3 | | |
| Windbreak Strip | | | | | | | | | | | |
| Various situations | Box | 14 | 8 | 4 | 6 | 2 | | 1 | | 1 | 2 |
| | Subterranean tile | 1 | 0 | 0 | 0 | | | | | | |
| | Metal can in box | 2 | 0 | 0 | 1 | | | 1 | | | |
| Totals | | 17 | 8 | 4 | 7 | 2 | | 2 | | 1 | 2 |
| Sand Pit | | | | | | | | | | | |
| | Flower pot | 2 | 2 | 0 | 1 | | | 1 | | | |
| | Subterranean tile | 1 | 0 | 0 | 1 | 1 | | | | | |
| | Subterranean metal | 2 | 0 | 0 | 2 | | | 1 | | 1 | |
| Totals | | 5 | 2 | 0 | 4 | 1 | | 2 | | 1 | |
| Miscellaneous situations | | | | | | | | | | | |
| | Box | 22 | 19 | 6 | 4 | 1 | 1 | | 1 | | 1 |
| | Subterranean tile | 4 | 0 | 0 | 1 | 1 | | | | | |
| | Flower pot | 2 | 1 | 0 | 0 | | | | | | |
| | Roofing paper cone | 12 | 0 | 7 | 0 | | | | | | |
| | Aerial box | 3 | 0 | 0 | 1 | | | | | | |
| Totals | | 43 | 20 | 13 | 6 | 2 | 1 | | 1 | 1 | 1 |
| Grand Totals | | 172 | 116 | 47 | 59 | 16 | 3 | 21 | 9 | 5 | 5 |

mice were found in one vacant domicile on the first cool day in late summer of 1953. Late in the season the bee colonies frequently are on the decline and rather weak and a number of the new queens of a colony may be destroyed by the mice. Mice may also be destructive early in the season before the colony has built up to a strength sufficient for its best defense. It is doubtful if a mouse would penetrate a colony with a full complement of workers. Narrowing the entrance size down to $\frac{1}{2}$ inch would probably solve the mouse problem.

In general, rodent nests are the preferred nesting sites of bumblebees. As Frison (1923) suggested, the chemotropism associated with the mice is probably unimportant. However, a rodent nest provides the proper material in a protected spot, requires little alteration and these are probably the reasons for the high acceptance of rodent nests by bumblebee queens.

A problem common to both Sladen's and Frison's work was the lack of mouse nests to place in the domiciles. A shortage of mouse nests was avoided by furnishing flax straw in the box and allowing the mice access to the box during the fall, winter and early spring. The mice worked the straw into a condition which was apparently very attractive to the searching queens.

In general field domiciles provide the four attributes which Frison (1923) felt necessary to a bumblebee nest, i.e., darkness, dryness, protection from the environment, and material to cover the comb. The domiciles protect the nests from vermin and rain damage, should provide conditions suitable for larger and stronger bumblebee colonies, and result in larger pollinating forces for the legume seed fields.

SUMMARY.—One hundred and fifty-four field domiciles, including wooden boxes, flower pots, roofing paper cones, and subterranean tiles were placed in fence rows, orchards, windbreaks, stump piles and various other situations. The wooden boxes were placed in the field in the fall and provided with flax straw. Field mice readily nested in the boxes in the fall, winter, and early spring. In the spring the mice were excluded by means of a metal plate placed over the large holes. These plates contained $\frac{5}{8}$-inch entrance holes for the bumblebees. Occupany of domiciles was as follows: 67 per cent by field mice, 27 per cent by ants, and 34 per cent by bumblebees. Ants which were a problem in the domiciles were readily controlled with dieldrin. Domiciles were accepted by *Bombus rufocinctus*, *B. separatus*, *B. borealis*, *B. fervidus* and *B. vagans* queens. The subterranean tiles and the flower pots were well accepted in dry locations but not occupied in poorly drained locations.

## LITERATURE CITED

**Frison, T. H.** 1918. Additional notes on the life history of *Bombus auricomus* Robt. Ann. Ent. Soc. Amer. **11**: 43–8.

**Frison, T. H.** 1926. Experiments in attracting queen bumblebees to artificial domiciles. JOUR. ECON. ENT. **19**: 149–55.

**Frison, T. H.** 1927. Experiments in rearing colonies of bumblebees (Bremidae) in artificial nests. Biol. Bull. **52**: 51–67.

**Hasselrot, T. B.** 1952. A new method for starting bumblebee colonies. Agron. Jour. **44**: 218–9.

**Lindhard, E.** 1912. Humlebien som Husdyr. Spredte Traek af nogle danske Humlebiartens Biologi. Tidsckr. Landbrugets Planteavl **19**: 335–52. (Original not read)

**Plath, O. E.** 1923. Breeding experiments with confined *Bremus* (*Bombus*) queens. Biol. Bull. **45**: 325–41.

**Plath, O. E.** 1934. Bumblebees and their ways. The Macmillan Co., New York, 201 gp.

**Sladen, F. W. L.** 1912. The bumblebee, its life history and how to domesticate it. The Macmillan Co., London. 283 pp.

# Tests on Insecticidal Control of Rice Water Weevil[1,2]

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In the past, control of the rice water weevil has depended on draining the rice fields as the larvae approach their peak of abundance and permitting the soil to become dry. Since the larvae are unable to survive in dry soil, control is thus accomplished. The fields are then reflooded and kept under water until drained for harvest. The drying and reflooding of fields creates extremely favorable conditions for the multiplication of temporary water species of mosquitoes. Two such species (*Psorophora confinnis* L.-A. and *P. discolor* Coq.) become so extremely abundant under such conditions that they have become a major problem throughout the rice areas of Arkansas. It therefore appears possible that insecticidal control of rice water weevil might also greatly alleviate the mosquito problem by bringing about less favorable ecological conditions for their development.

In order to test such possibilities, preliminary experiments were conducted in 1952 to determine what effect on rice water weevil populations insecticides might have. These tests showed sufficient

[1] Coleoptera: Curculionidae. *Lissorhoptrus simplex* (Say).

[2] Research paper 1123 of the Journal Series, University of Arkansas.

promise to justify more complete experiments in 1953. This paper is a report on these experiments.

After 4 years of intensive study of the rice water weevil (1930–1933 inclusive) Isely & Schwardt[3] concluded "The rice water weevil is the most important rice insect in Arkansas." They found its seasonal history to be as follows. Winter is spent as adults in almost any type of cover the weevils may find. They begin emerging in late April and feed on the leaves of various water grasses. Emergence continues over a period of several weeks, the peak of abundance occurring in late May or June. Although there may be some feeding on the leaves of unwatered rice, it is immediately after the first flooding that the fields are invaded by swarms of adult weevils. Eggs are deposited under the epidermis of the roots and larvae begin to appear in approximately 8 days. The first two stadia are completed within a week but the third and final stadium requires approximately 2 weeks. Another week or longer is spent in the pupal stage, after which the adults of the current season appear.

Although the feeding by the adult weevils results in considerable damage to the rice leaves, serious injury is not commonly encountered, and then, typically, is confined to relatively small areas. The serious damage caused by this species is the result of the larval feeding on the roots of the rice. Under conditions of heavy infestations the larvae destroy practically all the roots of rice and do not permit development of new roots until they cease their larval feeding and enter the pupal stage. Normally the rice survives the root destruction and sends out new roots as soon as the peak of larval feeding is passed. Although some larvae occur following this period their numbers typically are sufficiently small that they interfere but little with the further development of the rice. As a result the rice matures a crop despite heavy infestations but naturally the yield is reduced.

For the 1952 experiments, dieldrin and lindane were each used both as a spray and incorporated in bentonite granules or pellets.[4] In one half the plots the insecticides were applied at planting time and at the rates of 2.5 and 0.5 pounds per acre. The granular forms were applied by means of a fertilizer attachment to the drill used in drilling the rice. This resulted in the material being deposited in the soil just above the rice seed. The sprays were applied with a compressed air sprayer at 40 pounds pressure directly to the surface of the soil, immediately following the drilling of the rice. In the remaining plots all materials were applied to the entire surface of the soil just prior to the first flooding. In these plots the rate of application was either 1 pound or $\frac{1}{4}$ pound per acre. All plots were planted May 14 and flooded June 5. These plots contained approximately 1000 square feet each.

In making larval counts five stalks of rice were selected from each plot and the roots and mud surrounding them removed by hand. These were taken to the laboratory and washed over a double sieve by means of a fine, hard stream of water from a hose. The top sieve had four meshes per inch which removed the coarser materials. The bottom sieve had 20 meshes per inch which retained all but the smallest larvae. Counts were made of the larvae retained on the bottom screen. The treatments and plots were randomized. Counts were made on June 26 and July 3 and 11. Table 1 gives the total numbers of larvae found in the two replicates of each treatment.

Although the data in table 1 are inconclusive they indicate the following: (1) The smaller amounts applied immediately before flooding were more effective than the larger amounts applied at time of planting. (2) Materials incorporated in bentonite granules were less effective when buried in the ground just above the seed than when scattered on the surface. (3) Of the materials tested dieldrin was the more effective. (4) Dieldrin applied at the rate of $\frac{1}{4}$ pound per acre, either as a spray or as granules just previous to the first flooding, gave control.

In order to expand the work in 1953 it appeared necessary to develop a more rapid method of making larval counts than used in 1952. After trying a number of techniques the following was selected as being the most accurate and practical: Clumps of rice containing at least five plants, together with the soil surrounding the roots, were removed by hand. All but five plants and the excess soil was removed

[3] Isely, Dwight, and H. H. Schwardt. 1934. The rice water weevil. Agr. Exp. Sta. Bul. 299.

[4] For the preparation of these pellets see Whitehead, F. E. 1951. Rice Field Mosquito Control by Pellet-Borne Insecticide, Ark. Agr. Expt. Sta. Bul. 511.

Table 1.—Larval counts of rice water weevil in experimental plots. Stuttgart, Arkansas. 1952.

| Insecticide | Form | Applied at Time of Planting | | | Applied Immediately Before Flooding | | |
|---|---|---|---|---|---|---|---|
| | | Pounds per Acre | No. Larvae Collected | Per Cent Control | Pounds per Acre | No. Larvae Collected | Per Cent Control |
| Dieldrin | Spray | 2.5 | 1 | 99 | 1.0 | 2 | 97 |
| | Spray | 0.5 | 0 | 100 | 0.25 | 0 | 100 |
| | Pellets | 2.5 | 11 | 84 | 1.0 | 0 | 100 |
| | Pellets | 0.5 | 30 | 57 | 0.25 | 0 | 100 |
| Lindane | Spray | 2.5 | 8 | 89 | 1.0 | 2 | 97 |
| | Spray | 0.5 | 13 | 81 | 0.25 | 28 | 60 |
| | Pellets | 2.5 | 21 | 70 | 1.0 | 0 | 100 |
| | Pellets | 0.5 | 43 | 39 | 0.25 | 24 | 66 |
| Checks | | | 70 | | | | |

and discarded. Two such samples were taken and placed in 10-inch cylinder, constructed of sheet iron, the bottom of which was covered with 20-mesh copper screening. The cylinder was then placed in 6 to 12 inches of water and the roots of the rice clump shaken vigorously in the water within the cylinder, after which the clump was discarded. The larvae that are completely loosened from roots or soil by this treatment float to the surface. The floating larvae were counted and removed by means of a sieve. The cylinder was then shaken vigorously to dislodge additional larvae which were also counted and removed. This process was continued as long as it brought additional larvae to the surface. In most cases five to eight shakings completed the count. Numerous examinations of the materials remaining in the cylinder or in the clump of rice after this procedure showed that very few larvae were missed other than extremely small larvae capable of passing through the 20-mesh screen. Two samples were taken from each plot.

The plots in which insecticides were compared were 24 ft. square, each completely surrounded by a levee and each watered separately. A total of 120 such plots were constructed. Each insecticide was tested as a spray and in bentonite granules at either two or three dosages, replicated three times. All sprays were applied with a compressed air sprayer at 40 pounds pressure; the granules were scattered over the plots by hand. In all cases the insecticides were applied to dry soil and the plots flooded the same day. The rice was approximately 6 inches high at the time the applications were made. The tests required 96 plots. Those remaining were used as checks. All tests were randomized excepting that the two end plots of each of the 5 rows of plots were not used for insecticide tests. In making larval counts in these plots, each of three individuals made counts as previously described.

Since there was no significant difference between the sprays and pellets the data are combined in table 2. Thus the data in this table represents six replicates rather than three. The numbers in table 2 are the total numbers found in five counts taken at weekly intervals July 11 to Aug. 8 inclusive.

In this experiment aldrin and heptachlor at 8 ounces, dieldrin at 8, 4, and 2 ounces, and chlordane at 16 ounces per acre each gave at least 95 per cent control. Also aldrin at 4 ounces and chlordane at 8 ounces per acre gave between 90 and 95

Table 2.—Control of rice water weevil larvae in plots treated with insecticides, Stuttgart, Arkansas. 1953.

| Insecticide | Ounces per Acre | Number Larvae | Per Cent Control |
|---|---|---|---|
| Aldrin | 8 | 7 | 99 |
| | 4 | 36 | 94 |
| | 2 | 81 | 86 |
| Chlordane | 16 | 27 | 95 |
| | 8 | 53 | 91 |
| | 4 | 66 | 88 |
| DDT | 16 | 198 | 65 |
| | 8 | 304 | 46 |
| Dieldrin | 8 | 8 | 99 |
| | 4 | 15 | 97 |
| | 2 | 31 | 96 |
| Hepthchlor | 8 | 28 | 95 |
| | 4 | 100 | 82 |
| | 2 | 107 | 81 |
| Toxaphene | 16 | 64 | 89 |
| | 8 | 148 | 74 |
| Checks | — | 564 | — |

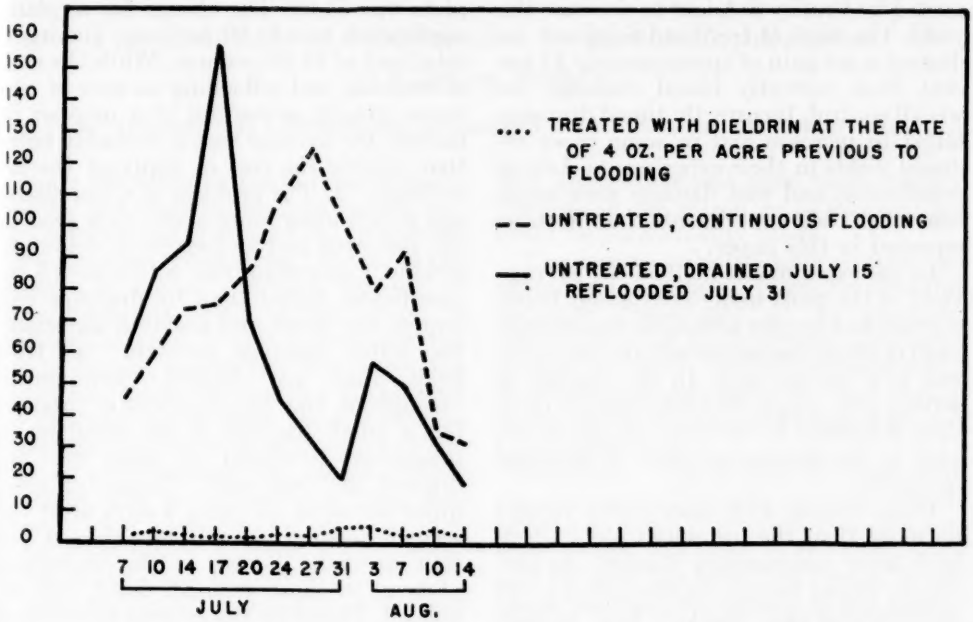


FIG. 1.—Effects of various treatments on populations of rice water weevil larvae, Stuttgart, Arkansas, July–August 1953.

per cent control. It should be noted that there was a very light infestation in the experimental plots in 1953, as only 564 larvae were found in the check plots. Also damage from root destruction was very light. However it is believed that in the presence of heavy infestations 90 per cent control or higher would be satisfactory. It therefore appears that a number of the insecticides tested may be recommended after confirming data on the control of rice water weevil are obtained.

In addition to the work discussed above experiments were also conducted on two other series of plots. In one of the series consisting of nine $\frac{1}{4}$-acre plots, three were treated with dieldrin at the rate of 4 ounces per acre, flooded immediately and kept continuously flooded until drained for harvest. None of the remaining six plots received any insecticidal treatment. Three of them were flooded continuously; the remaining three were flooded but drained at the proper time to control the weevil, permitted to dry. and reflooded 15 days later.

The second series consisted of 18 $\frac{1}{4}$-acre plots. In this series the plots were treated as in the preceding series excepting that three pairs of plots were treated and six pairs untreated. One of each pair was drained July 15 and reflooded July 31, whereas the second plot of each pair was flooded continuously. In these plots counts were made as previously described except that two counts were taken weekly instead of one. Yield records were taken on these latter two series.

Figure 1 shows the average population of weevil larvae of these two series during the period from July 7 to August 14 inclusive.

In plots treated with dieldrin at 4 ounces per acre populations were extremely light during the entire season, Figure 1. Drainage markedly reduced larval populations. On July 31, 16 days after drainage, there was an average of 19 larvae in each of the drained plots as compared to 102 in the undrained plots. Prior to drainage populations had been heavier in the plots that were later drained. When the drained plots were reflooded, there was a rise in population even though the seasonal decline had started in undrained plots. Part of this rise in numbers of larvae collected may have been due to difficulty of removing larvae from dry soil. However, the population in drained plots never again became as great as in the undrained plots.

Drainage and drying of the soil is re-

ported by Cralley & Adair[5] to decrease the yield. The work of Isely and Schwardt indicated a net gain of approximately 18 per cent from correctly timed drainage for weevil control. Incorrectly timed drainage failed to increase and in some cases reduced yields in their experiments. Larval populations and root damage were much heavier in their experiments than in those reported in this paper.

In the experiments in 1953 the average yield of the plots under continuous flooding was 49.3 bu. per acre while the average yield of those drained, dried, and reflooded was 43.9 bu. per acre. In the absence of serious root injury this reduction of more than 5 bushels to the acre can be attributed to the depressing effect of drainage on yields.

Plots treated with insecticides yielded no more than the untreated plots where both were continuously flooded. As previously stated the weevil infestation in the experimental plots was very light in 1953. The application of insecticides appeared to have no deleterious effects on plant growth. Although it remains to be proven, it may be supposed that under conditions of heavy infestation, the treatments applied in these tests would prevent the heavy root destruction characteristic of heavy infestations and thus increase yields.

Should future experiments prove that the results obtained in these preliminary experiments may be regularly obtained, it appears that the practice of weevil control by insecticides may be of four-fold benefit to rice growers: (1) The data indicate insecticidal control to be more effective than drainage and drying, and the depressive effect of drainage on yields would be avoided. (2) Insecticidal control is less expensive. The retail price of the 4 ounces of dieldrin applied in the larger plots was $1.00. The charge for airplane application was $1.00 per acre, making a total cost of $2.00 per acre. While the cost of draining and reflooding an acre of rice varies greatly according to a number of factors, the average cost is probably more than double the cost of applying the insecticide. (3) The problem of water shortage is becoming more acute each year in the rice area and at present is definitely serious. Controlling rice water weevil by insecticides rather than by drainage will require less water and alleviate materially the water shortage problem. (4) Rice fields that are flooded continuously throughout the growing season produce but a small fraction of the numbers of mosquitoes produced by those that are drained and reflooded. Counts of mosquito larvae in all plots 4 days after the second flooding showed less than 1 per cent as many larvae in the undrained plots as in those drained, dried, and reflooded. Therefore the general adoption of insecticidal control of the rice water weevil rather than control by drainage should greatly relieve the serious mosquito problem of the rice area.

SUMMARY.—Aldrin, dieldrin, heptachlor, DDT, chlordane, and toxaphene were applied to rice in an attempt to control the rice water weevil *Lissorhoptrus simplex* (Say). The first three materials were used at the rates of 8, 4, and 2 ounces per acre; the others at 16 and 8 ounces per acre. Although extensive data for but one season are available the results are sufficiently promising to make it appear that low dosages of a number of materials, applied just prior to the first flooding, would give satisfactory control of rice water weevil.

[5] Cralley, E. M. and Roy C. Adair. Effect of irrigation treatments on stem rot severity, yield and quality of rice. 1943. Adm. Soc. Agron. 35 (6) 499–576.

# The Relation of Insecticides to Insect Populations in Cotton Fields[1]

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Since the introduction of organic insecticides, and their widespread use on cotton, a great deal of anxiety has frequently been expressed concerning "upsetting the balance of nature" through the use of these materials. Much of this anxiety is justified, since it is well known that the use of certain insecticides to control one insect has frequently resulted in the need for the control of another. Presumably the destruction of the natural enemies of the pest or pests created the second control problem. The ideal insecticide from this point of view, therefore, would be one that would control the injurious species without disturbing the beneficial ones.

The relation of the schedule of applications to control and to the total seasonal insect population must also be considered. Altering the schedule of applications might control the injurious species without disturbing too much the beneficial species. For example, if control of the boll weevil could be accomplished early in the season before the buildup of beneficial insects, there would be no problem of their later destruction.

Newson & Smith (1949) reported on the relation between the use of some organic insecticides on cotton and the population of certain predaceous insects and showed that all these populations were reduced below those in the checks.

MATERIALS AND METHODS.—Several large-scale experiments conducted for the control of cotton insects near Waco, Tex., in 1949 afforded an opportunity for a study of the over-all insect population in fields treated with toxaphene or toxaphene-sulfur, or with DDT mixed with various combinations of BHC, chlordane, toxaphene, or sulfur. Both spray and dust formulations were included, and the treatment schedules were varied. The plots ranged from 2 to 20 acres in size, averaging about 10 acres.

The insect populations in the various plots were recorded from sweepings with a 16-inch collecting net, 100 sweeps being made near the center of each plot. Sweepings were begun immediately after the first application and were made weekly throughout the season, or as long as they could be conveniently made.

The insects collected were recorded as injurious or beneficial. Insects of doubtful economic importance as, for example, many species of Diptera were not placed in either category. Identifications of many of the species were made by taxonomists in the former Bureau of Entomology and Plant Quarantine.

RESULTS.—The results of these tests are summarized in tables 1 and 2. Each treatment reduced the injurious forms to some extent, but most of the treatments also reduced the beneficial forms. Toxaphene was less destructive of the beneficial forms than BHC or chlordane. The addition of DDT to toxaphene increased the toxicity to beneficial species. In four early-season spray applications toxaphene was the most successful treatment from the standpoint of low mortality to the beneficial species.

**Table 1.—Effect of various sprays used for control of cotton insects on injurious and beneficial forms.**

| Pounds of Active Ingredients per Acre[1] | Per Cent Reduction under Check[2] | |
|---|---|---|
| | Beneficial Forms | Injurious Forms |
| Toxaphene 1+DDT 0.5 | −2 | 63 |
| Chlordane 1+DDT 0.5 | 35 | 70 |
| 0.75+DDT 0.5 | −7 | 62 |
| Toxaphene 1 | −18 | 53 |

[1] Spray dosage 2.5 gallons per acre; applied on May 18 and 25, June 1 and 8.
[2] Sweepings made on June 14 and 29, July 8 and 13.

Early dusts followed by later sprays could not be compared with early sprays followed by later dusts on the basis of reduction in population over the untreated check, because no check was included. These treatments were therefore compared on the basis of the average number of beneficial and injurious forms collected

[1] Report of a study made under the Research and Marketing Act of 1946, in cooperation with the Texas Agricultural Experiment Station.

Table 2.—Effect of various dusts used for control of cotton insects on injurious and beneficial forms.

| Insecticide, Per Cent | Pounds of Dust per Acre | Date of Application | Per Cent Reduction Under Check[1] | |
|---|---|---|---|---|
| | | | Beneficial Forms | Injurious Forms |
| Toxaphene 20+sulfur 40 | 12 | June 2, 9, 20 | −10 | 36 |
| | 12 | June 2, 9, 20 | 17 | 56 |
| | 15 | July 8, 12, 18, 20, 27 | | |
| BHC (g.i.) 2+DDT 10+sulfur 40 | 12 | June 1, 8 | 27 | 68 |
| Chlordane 10+DDT 5+sulfur 40 | 12 | June 1, 8 | 60 | 67 |
| Chlordane 10+DDT 5+sulfur 40 | 12 | June 1, 8 | 63 | 68 |
| | 15 | July 18, 22 | | |

[1] Based on six collections made between June 22 and July 28.

per 100 net sweeps. These data are summarized in table 3.

Toxaphene-sulfur dust applied after two early-season toxaphene-DDT sprays gave the lowest population of injurious insects and highest population of beneficial insects.

Discussion.—For a few of the most abundant species in the collections the following reports are given:

*Beneficial Insects.*—The greatest number of spiders were collected in the plot treated with toxaphene-DDT spray at the 1+0.5 pound dosage in four early applications. There were 43.2 specimens collected per 100 sweeps, or a reduction under the untreated check of only 6.4 per cent. This treatment apparently had little effect on the seasonal population of spiders, for they survived in great numbers. Spiders may not be affected by the insecticides in the same physiological manner as are many of the insects. The spiders in cotton usually inhabit flowers or terminals. However, one may often see the black widow, *Latrodectus mactans* (F.), among the foliage.

Of the beneficial Hemiptera, a flower bug, *Orius insidiosus* (Say), was the most abundant as well as one of the more important species economically. It readily consumed many bollworm eggs and at times completely controlled what apparently would have been a serious infestation of the bollworm (Ewing & Ivy 1943). The greatest number of adults and nymphs, 8 per 100 sweeps, were taken in the plot treated with toxaphene-sulfur dust at 12 pounds per acre. Many were taken in the plots treated with the toxaphene-DDT spray in each of four early applications. The fewest specimens, 0.5 per 100 sweeps, were collected in the plots treated with chlordane-DDT spray at the 1+0.5 pound dosage.

*Geocoris* populations varied consider-

Table 3.—Effect against injurious and beneficial insects and spiders of early dusts followed by later sprays and early sprays followed by later dusts used in cotton insect control experiments at Waco, Tex., in 1949.

| Treatment | Dosage per Acre | Dates of Application | Average Number per 100 Sweeps[1] | |
|---|---|---|---|---|
| | | | Beneficial Forms | Injurious Forms |
| Spray followed by dust: | | | | |
| Toxaphene-DDT (1+0.5 lb.) | 2.5 gal. | May 28, June 8 | | |
| Toxaphene-sulfur (20+40%) | 15 lb. | July 23 | 44 | 20 |
| Dust followed by spray: | | | | |
| Schedule 1— | | | | |
| BHC-DDT-sulfur (3-5-40%) | 15 lb. | July 1, 9 | | |
| Toxaphene-DDT (1.67+0.83 lb.) | 7.5 gal. | July 15, 22 | 37 | 27 |
| Schedule 2— | | | | |
| BHC-DDT-sulfur (3-5-40%) | 15 lb. | July 2, 10, 18 | | |
| Toxaphene-DDT (1.5+0.75 lb.) | 7.5 gal. | July 23 | 30 | 25 |

[1] Based on five collections made between June 22 and July 27.

ably, the greatest number being taken in the plot treated with chlordane-DDT spray at 1 pound of chlordane and 0.5 pound of DDT per acre in four early applications. In many of the treated plots no *Geocoris* were taken. In some of the experiments appreciable reductions were shown with toxaphene and BHC, whereas in others more *Geocoris* were collected than in the untreated check. Newson & Smith (1949) reported that toxaphene and BHC-DDT-sulfur significantly reduced the numbers of predaceous Hemiptera (*O. insidiosus* and *G. punctipes*) in comparison with calcium arsenate-nicotine treatments.

Many of the Coleoptera taken belonged to the family *Coccinellidae*. The species most commonly collected were *Hippodamia convergens* Guer. (the convergent lady beetle), *Coleomegilla maculata* (Deg.), *Cycloneda sanguinea* (L.), *Scymnus creperus* Muls., *S. collaris* Melsh., *S. loewi* Muls., *Hyperaspis fimbriolatus* Melsh., *H. undulata* (Say), *Olla abdominalis* (Say), and *Psyllobora taedata* Lec. In general, the coccinellids were apparently least affected in the plots treated with toxaphene spray. Fewest specimens of the convergent lady beetle were collected in the field dusted with BHC-DDT-sulfur and then sprayed with toxaphene-DDT. The chlordane-DDT-sulfur dust did not appear to affect the species of *Scymnus*, as did other treatments.

A small beetle, *Melanophthalma distinguenda* (Com.), belonging to the family Lathridiidae, appeared through most of the season in the majority of the plots and was least affected in the one treated with toxaphene dust. This beetle is reported to be predaceous on eggs of the bollworm moth (Ewing & Ivy 1943). A small pubescent beetle, *Hydnocera pubescens* Lec., was least affected in the plot sprayed with toxaphene-DDT. This clerid is reported to be parasitic upon the larvae of the boll weevil (Clausen 1940). Several species of *Collops* (Malachiidae) were collected in greatest numbers in the plot sprayed with toxaphene at the rate of 1 pound per acre. *Collops* spp. are known to feed on eggs of the bollworm (Ewing & Ivy 1943), leafhoppers, the alfalfa weevil, and the alfalfa caterpillar (Clausen 1940). Small beetles belonging to the family Phalacridae were affected by most of the treatments, as no specimens were collected in many of the treated plots. However, they were less affected in plots receiving two early applications. Members of the Phalacridae are considered predaceous, and at various times were observed feeding on the cotton aphid, *Aphis gossypii* Glov.

Other beneficial insects were collected, but in insufficient numbers for definite conclusions to be made.

*Injurious Insects.*—Mirids were collected in greatest numbers in the plot receiving the toxaphene dust at 12 pounds per acre in early applications. Fewest mirids were collected in the plot sprayed with toxaphene-DDT at 1+0.5 pound in early applications. A few of the common species of mirids represented in the collections were *Adelphocoris rapidus* (Say), *Psallus seriatus* (Reut.), *Polymerus basalis* (Reut.), *Rhinacloa forticornis* Reut., *Reuteroscopus ornatus* (Reut.), and *Lygus linelaris* (P. de B.).

The pentatomid population varied considerably, but appreciable reductions were found in some of the plots sprayed with toxaphene in four early applications. However, in some of the toxaphene-DDT plots and the chlordane-DDT plots they were least affected. A few of the species most commonly taken were *Thyanta custator* (F.), *Nezara viridula* (L.), *Acrosternum hilare* (Say), *Euchistus servus* (Say), *Podisus maculiventris* (Say), *Solubea pugnax* (F.), and *Trichopepla semivittata* (Say).

Many species of Homoptera are known to damage cotton. The western potato leafhopper, *Empoasca abrupta* DeL., was the most abundant species collected. Toxaphene-DDT spray followed by a late application of toxaphene-sulfur dust appeared to be more toxic to the Homoptera than the other treatments. Chlordane was not outstandingly effective against the leafhoppers. Similar results with chlordane were reported by Sun *et al.* (1948) against the potato leafhopper, *E. fabae* (Harr.).

Of the injurious species of Coleoptera taken, the greatest number belonged to the Chrysomelidae. They were least affected in most of the toxaphene-treated plots. The fewest chrysomelids were collected in the plot treated with a spray formulation of 1 pound of chlordane and 0.5 pound of DDT per acre. The corn flea beetle, *Chaetocnema pulicaria* Melsh., was the most abundant species collected, with fewer numbers of *Diabrotica undecimpunc-*

*tata* Mann., *Acalymma vittata* (F.), *Pachybrachis immaculatus* (Jac.), *P. diversus* (Fall.), and *Altica foliacea* (Lec.).

SUMMARY.—The total population of insects and spiders occuring in experimental cotton fields near Waco, Tex., in 1949 was studied in relation to the use of various insecticide treatments for the control of cotton insects. In general, early applications permitted a greater survival or increase of beneficial forms than later applications, while at the same time causing a great reduction in injurious forms.

Toxaphene-sulfur dust applied after two early-season toxaphene-DDT sprays gave the lowest population of injurious insects and the highest population of beneficial insects.

## LITERATURE CITED

**Ewing, K. P.**, and E. E. Ivy. 1943. Some factors influencing bollworm populations and damage. JOUR. ECON. ENT. **36**: 602–6.

**Newsom, L. D.**, and C. E. Smith. 1949. Destruction of certain insect predators by application of insecticides to control cotton pests. JOUR. ECON. ENT. **42**: 904–8.

**Clausen, C. P.** 1940. Entomophagous Insects. Ed. I, 688 pp. McGraw-Hill, New York and London.

**Sun, Yun-Pei**, W. A. Rawlins, and Leland B. Norton. 1948. Comparative toxicity of chlordan, DDT, benzene hexachloride and chlorinated camphene. JOUR. ECON. ENT. **41**: 91–7.

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# Translocation of Systox in the Cotton Plant[1]

MOSTAFA KAMAL AHMED,[2] L. D. NEWSOM, J. S. ROUSSEL and R. B. EMERSON

Systox is one of the systemic insecticides which is absorbed by plants, travels in the sap stream, and is translocated to other parts of the plant in amounts sufficient to kill some species of pests feeding on those parts. Little information is available concerning the conducting tissues of plants involved in the translocation of this insecticide. Such information seems to be necessary in order to develop the most effective methods of application. In the case of cotton it is particularly desirable to know whether or not it is translocated into the seed since various feeds and food products are produced from cotton seed. The studies reported here were designed to obtain information on these points.

METHODS AND MATERIALS.—Methods used by Curtis (1925), Mason & Maskell (1928) and Phillis & Mason (1940) in their studies of the transfer of solutes in plants were used with some modifications in this study of the transfer of Systox in the cotton plant.

Cotton of the variety Deltapine 15 was grown in the greenhouse in 8-inch unglazed clay pots. Plants were thinned to one per pot. Experiments were begun when the plants were 2 months old. At this time they were 12 to 15 inches tall with seven to nine well developed leaves. A few days before the start of an experiment the plants used were infested with the cotton aphid, *Aphis gossypii* Glov., by attaching infested leaves to the petioles of all the leaves on the plants.

Each experiment was replicated five times. Aphids were counted on each leaf of each plant in the experiments at the beginning of the test and at intervals of either 2 or 6 hours until the test was terminated. Reduction in aphid populations was taken as an indication that toxic amounts of the insecticide were present in that portion of the plant on which the insects were feeding.

Systox,[3] principally the 0, 0-diethyl-0-2-(ethylmercapto)-ethyl thiophosphate, was used diluted 1-800 with water in the tests. Additional tests were conducted using Systox[4] tagged with sulphur$^{35}$. This radioactive Systox had a specific activity of 4.7 millicuries per milligram. It was used at the same dilution as the regular Systox.

Radioactivity was measured in all the leaves of plants treated with the radioactive Systox. Leaves were removed from the plants 48 hours after treatment and dried separately at 60 degrees C. for 24 hours. They were then ground to a powder, placed in small vials, and stored over

[1] The data in this paper are taken in part from a dissertation submitted by Mostafa Kamal Ahmed in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Entomology, Louisiana State University, Baton Rouge, Louisiana.

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[3] Furnished by the Chemagro Corporation.

[4] Prepared at Oklahoma A & M College and furnished by the Chemagro Corporation.

calcium chloride in a dessicator until ready for counting.

When ready for counting a sample from each vial was transferred to a watch glass 26 mm. in diameter. The mounted sample was then placed in a reproducible position beneath the window of a Geiger-Muller end-window tube which was installed in a vertical lead shield. This equipment was operated in an insulated room in which the temperature was maintained at about 70 degrees F. and the relative humidity at about 50 per cent. Counting rates were corrected for background, resolving time, and progressive decay of the sulphur$^{35}$ to give values in terms of number counts/minute/milligram of sample. Care was taken to use approximately equal amounts of each sample and to distribute them equally over the watch glass in such a manner as to present approximately equivalent surface areas for each measurement.

Studies on the upward movement of Systox were conducted on four groups of cotton plants treated as follows:

1. A ½-inch section of all tissues outside the xylem was removed from the stem at a point between the first and second nodes. Exposed tissues were coated with vaseline to reduce loss of water. A small calibrated vial containing exactly 2 c.c. of the diluted Systox was attached to the cut petiole of the first leaf, figure 1.

2. The blade of the leaf arising from the first node was cut off and the phloem and xylem tissues of the stem separated with a scalpel so that the petiole of the leaf was attached only to the phloem tissue of the stem, figure 2. Vaseline was applied to both surfaces of the wound and a piece of waxed paper inserted between the tissues to assure separation between the tissues, figure 3. The separated tissues were wrapped in their normal position with adhesive tape. A vial containing 2 c.c. of the diluted Systox was attached to the cut petiole.

3. Same as in group 2 but with no application of Systox.

4. Systox applied in the manner described above to the cut petiole of the leaf arising from the first node of otherwise normal plant.

Similar experiments, except group 3 which was omitted, were conducted with Systox tagged with sulphur$^{35}$.

All operations were performed in the early morning since Mason & Maskell (1928) found that the indirect effects of ringing, notably the development of air bubbles, were avoided, provided the ringing was done in the early morning before the transpiration pull became operative.

Studies on the downward movement of Systox were conducted on four groups of cotton plants treated as follows:

1. A ½-inch section of xylem was removed from the stem at a point between the fifth and sixth nodes. A longitudinal cut was made through the tissues external to the xylem with a scalpel. Then the phloem tissues were carefully separated from the xylem with the tip of the scalpel and the section of xylem removed with scissors. Vaseline was quickly applied to the exposed tissues to reduce loss of water, figure 4. Blades of all leaves and the leaf buds above the fifth node were removed prior to the operation and the cut surfaces coated with vaseline to reduce loss of water. A vial containing 2 c.c. of the diluted Systox was attached to the cut petiole of the sixth leaf.

2. Same as in group 1 but with no application of Systox.

3. A ½-inch section of all tissues outside the xylem was removed from the stem between the fifth and sixth nodes and plants treated as described for group 1.

4. Systox applied as in group 1 to the cut petiole of leaf arising from the fifth node of an otherwise normal plant.

Similar experiments, with the omission of group 2, were conducted using Systox tagged with sulphur$^{35}$.

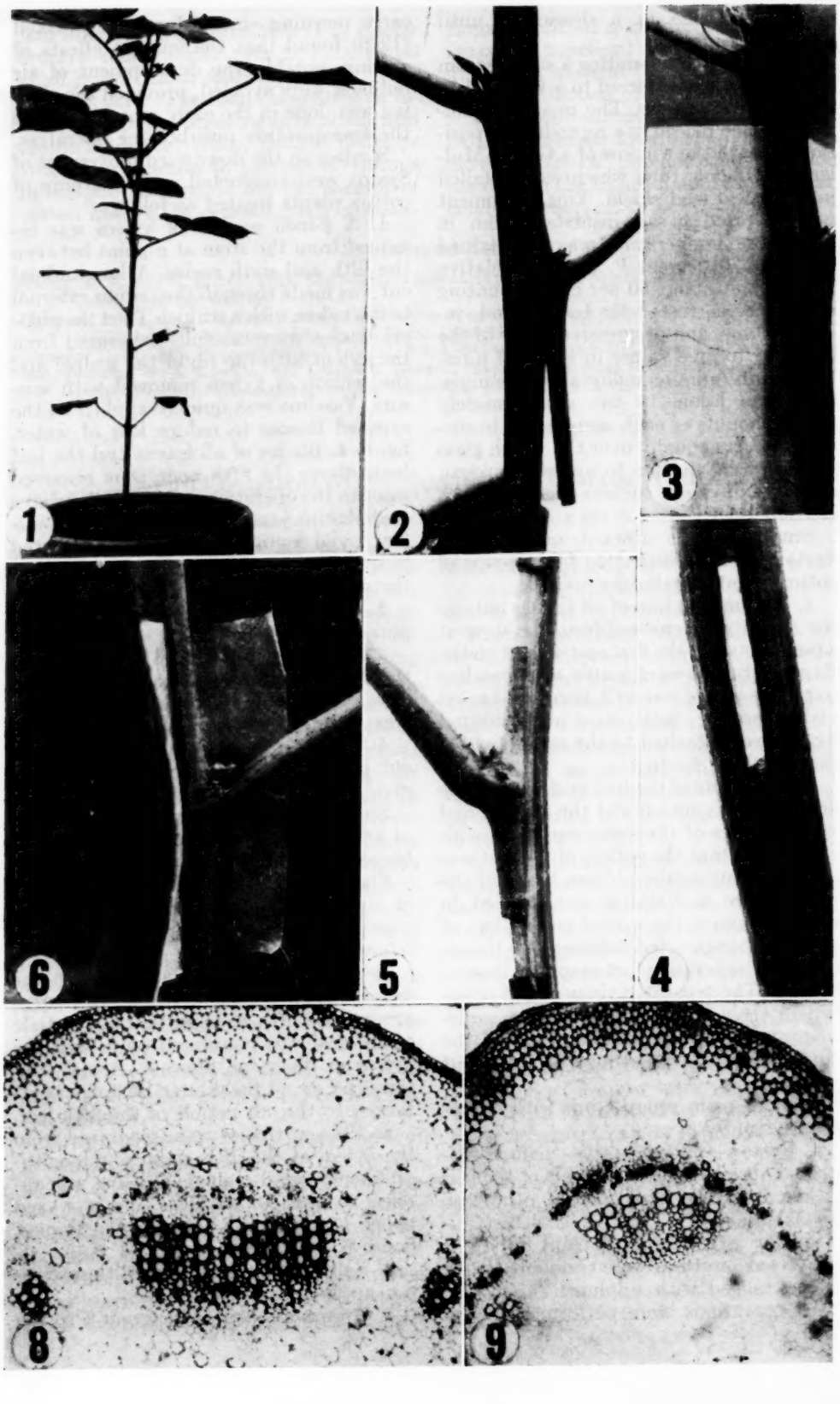
Studies on the simultaneous movement of Systox in both directions were conducted on four groups of plants treated as follows:

1. Strips of all tissues external to the xylem were removed from the stem around the fifth node so that the petiole of the leaf was connected only with the xylem of the stem, figure 5. A vial containing 2 c.c. of the diluted Systox was attached to the cut petiole of the fifth leaf.

2. Phloem tissues were separated from the xylem at the fifth node by a longitudinal cut with a scalpel. Vaseline was applied to the cut surfaces and a waxed paper was inserted between the tissues, figure 6.

3. Same as in group 2 but with no Systox applied.

4. Systox applied as in group 1 to the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cut petiole of the fifth leaf of an otherwise normal plant.

Similar experiments, with the omission of group 3, were conducted using Systox tagged with sulphur[35].

Transfer of Systox into the cotton fruit was studied by treating cotton plants grown in soil beds in the greenhouse with Systox tagged with sulfur[35]. Application was made by the cut petiole method to fruiting branches arising from the main stem as illustrated in figure 7. The vial containing the radioactive Systox which was diluted 1:800 with water was left attached to the cut petiole for 24 hours by which time from 1.5 to 2 c.c. of the material had been taken into the plant.

Two different types of experiments were conducted. In the first, treatment was made to a group of blossoms as soon as they opened. Some of these were measured for radioactivity 24 hours after treatment. The remainder was left for varying periods of time and radioactivity was measured in bolls after they became 7, 14, 21, 28 and 35 days old. In the second experiment a group of flowers opening on the same day was treated 6, 13, 20, 27 and 34 days after flowering and samples of each were taken 24 hours after treatment.

Since the primary interest was to see how much Systox could be translocated into the seeds, samples of seeds from each boll were collected and radioactivity was measured in them alone. It was difficult to obtain seed from bolls 7 days old because of their small size. In this case the whole boll was used for analysis. In bolls 14 days old or older one locule was used to measure radioactivity of the boll. Samples of seeds and burs were taken separately from the remaining locules and radioactivity was measured in each. Radioactivity was also measured in the leaf arising at the node from which the fruit was taken.

Techniques described above were used for measuring radioactivity.

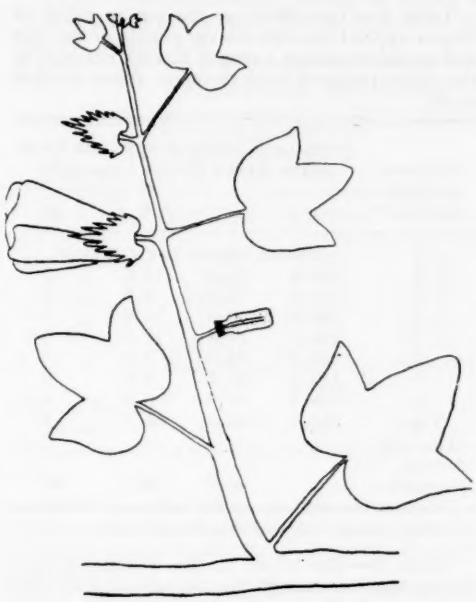

FIG. 7. Diagram showing method of application of radioactive Systox to fruiting branches.

DISCUSSION OF RESULTS.—Results are summarized in tables 1 to 16 inclusive. Under the experimental conditions described translocation of Systox occurred only in the xylem tissues of the cotton plant. In all cases where the xylem of the stem was left connected to that of the petiole through which the application was made complete kill of all aphids on the leaves above the site of application was obtained within 12 hours, tables 1 and 4. Movement of the insecticide in an upward direction toward the growing point of the plant was rapid as indicated by the time required to obtain high mortality of the aphids on the topmost leaf of the plant. For example, an average of 96.7 per cent mortality of aphids was observed on the eighth leaf 6 hours after application, table 1.

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FIG. 1.—Plant showing ring of tissues external to xylem removed and vial containing Systox attached to cut petiole of first leaf.

FIG. 2.—Method used to separate xylem tissues of stem from leaf petiole.

FIG. 3.—Method of keeping xylem tissues of stem and petiole separated with waxed paper.

FIG. 4.—Stem showing section of xylem removed.

FIG. 5.—Stem showing strips of tissues external to xylem removed around base of petiole.

FIG. 6.—Method of separating xylem of stem from petiole leaving phloem connected to stem both above and below point of separation.

FIG. 8.—Cross section of petiole showing discoloration of xylem resulting from application of Systox to leaf blade.

FIG. 9.—Cross section of petiole from untreated leaf showing normal appearance of xylem.

**Table 1.—The effect on the cotton aphid of Systox applied through the cut petiole of the first leaf to plants having a ring of tissues external to the xylem removed from the stem above the first node.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | |
|---|---|---|---|---|
| | 0 | 2 | 6 | 12 |
| 1 | Systox applied to cut petiole[1] | | | |
| 2 | 151.8 | 98.6 | 18.6 | 0 |
| 3 | 156.6 | 73.8 | 4.6 | 0 |
| 4 | 133.8 | 63.8 | 16.8 | 0 |
| 5 | 124.0 | 74.8 | 11.2 | 0 |
| 6 | 155.2 | 84.2 | 7.8 | 0 |
| 7 | 117.8 | 56.2 | 6.0 | 0 |
| 8 | 96.4 | 47.8 | 3.2 | 0 |
| Total | 935.6 | 499.2 | 68.2 | 0 |
| Per cent decrease in population | | 46.6 | 92.7 | 100 |

[1] Average amount of Systox absorbed was 0.96 c.c.

**Table 2.—The effect on the cotton aphid of Systox applied through the cut petiole of the first leaf connected to the stem by phloem tissue only.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | |
|---|---|---|---|---|
| | 0 | 2 | 6 | 12 |
| 1 | Systox applied to cut petiole[1] | | | |
| 2 | 95.6 | 99.2 | 108.2 | 113.2 |
| 3 | 145.4 | 151.0 | 165.6 | 176.8 |
| 4 | 149.0 | 154.6 | 161.8 | 162.4 |
| 5 | 89.4 | 94.0 | 99.8 | 109.2 |
| 6 | 101.0 | 109.2 | 120.8 | 128.4 |
| 7 | 106.6 | 110.2 | 120.6 | 122.8 |
| 8 | 116.0 | 119.4 | 128.0 | 131.8 |
| Total | 803.0 | 837.6 | 904.8 | 944.6 |
| Per cent increase in population | | 4.3 | 12.7 | 17.6 |

[1] Average amount of Systox absorbed was 0.12 c.c.

**Table 3.—The effect on populations of the cotton aphid of separating phloem and xylem tissues at the first node so that the leaf is connected to the stem by phloem tissue only.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | |
|---|---|---|---|---|
| | 0 | 2 | 6 | 12 |
| 1 | No Systox applied | | | |
| 2 | 135.4 | 142.2 | 156.4 | 167.0 |
| 3 | 92.4 | 101.0 | 110.4 | 119.8 |
| 4 | 111.2 | 119.8 | 129.4 | 136.2 |
| 5 | 104.4 | 106.6 | 108.6 | 108.0 |
| 6 | 128.2 | 134.2 | 135.4 | 128.8 |
| 7 | 141.8 | 149.6 | 156.4 | 158.6 |
| 8 | 125.4 | 150.8 | 159.0 | 172.2 |
| Total | 838.8 | 902.2 | 955.6 | 990.6 |
| Per cent increase in population | | 7.8 | 13.9 | 18.1 |

**Table 4.—Effect on the cotton aphid of Systox applied through the cut petiole of the first leaf of otherwise normal plant.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | |
|---|---|---|---|---|
| | 0 | 2 | 6 | 12 |
| 1 | Systox applied to cut petiole[1] | | | |
| 2 | 149.0 | 80.6 | 17.8 | 0 |
| 3 | 128.2 | 60.6 | 7.0 | 0 |
| 4 | 98.0 | 31.4 | 4.6 | 0 |
| 5 | 135.0 | 67.8 | 17.0 | 0 |
| 6 | 132.6 | 62.8 | 8.0 | 0 |
| 7 | 127.4 | 52.2 | 4.8 | 0 |
| 8 | 96.0 | 37.2 | 7.2 | 0 |
| Total | 866.2 | 392.6 | 66.4 | 0 |
| Per cent decrease in population | | 54.7 | 92.3 | 100 |

[1] Average amount of Systox absorbed was 1.32 c.c.

**Table 5.—Radioactivity shown in leaves of plants where radioactive Systox applied to the cut petiole of the first leaf.**

| Position of Leaf on Plant | Counts/Minute/Milligram | | |
|---|---|---|---|
| | Tissues External to Xylem Removed | Petiole Connected to Stem by Phloem Only | Normal Plant |
| 1 | Radioactive Systox applied to cut petiole | | |
| 2 | 35.53 | 0.05 | 21.93 |
| 3 | 51.07 | 0.07 | 41.14 |
| 4 | 78.80 | 0.10 | 43.44 |
| 5 | 16.70 | 0.06 | 13.89 |
| 6 | 70.98 | 0.07 | 71.46 |
| 7 | 42.71 | 0.05 | 41.14 |
| No. cc. Systox absorbed | 2.4 | 0.25 | 2.0 |

**Table 6.—Effect on the cotton aphid of Systox applied through the cut petiole of the sixth leaf to plants having a ring of tissues external to the xylem removed from the stem above the fifth node.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 48 | 72 |
| 1 | 143.6 | 155.8 | 151.6 | 58.8 | 0 |
| 2 | 122.0 | 122.2 | 114.6 | 41.2 | 0 |
| 3 | 179.4 | 96.0 | 33.8 | 1.6 | 0 |
| 4 | 178.4 | 74.4 | 8.8 | 0.6 | 0 |
| 5 | 197.6 | 64.0 | 14.6 | 0 | |
| 6 | Systox applied to cut petiole[1] | | | | |
| Total | 821.0 | 512.4 | 323.4 | 102.2 | 0 |
| Per cent decrease in population | | 37.6 | 60.6 | 87.6 | 100 |

[1] Average amount of Systox absorbed was 1.62 c.c.

**Table 7.—The effect on the cotton aphid of Systox applied to the cut petiole of the sixth leaf of plants with a section of xylem removed from the stem between the fifth and sixth nodes.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 48 | 72 |
| 1 | 91.6 | 100.4 | 102.0 | 105.6 | 118.0 |
| 2 | 115.2 | 127.8 | 141.8 | 160.6 | 160.5 |
| 3 | 117.6 | 133.4 | 148.8 | 151.8 | 154.8 |
| 4 | 119.6 | 133.2 | 143.6 | 161.6 | 148.3 |
| 5 | 116.8 | 136.4 | 183.8 | 201.2 | 229.5 |
| 6 | Systox applied to cut petiole[1] | | | | |
| Total | 560.8 | 631.2 | 720.0 | 780.8 | 811.1 |
| Per cent increase in population | | 12.6 | 28.4 | 39.2 | 44.6 |

[1] Average amount of Systox absorbed was 0.64 c.c.

**Table 8.—The effect of removing a section of xylem tissue between the fifth and sixth nodes on populations of the cotton aphids.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 48 | 72 |
| 1 | 107.2 | 117.8 | 122.6 | 115.6 | 101.8 |
| 2 | 121.4 | 125.0 | 107.2 | 120.2 | 136.8 |
| 3 | 103.4 | 112.4 | 127.8 | 143.0 | 154.5 |
| 4 | 118.2 | 126.2 | 128.6 | 149.8 | 140.8 |
| 5 | 187.2 | 192.0 | 215.4 | 228.2 | 215.3 |
| 6 | No Systox applied to cut petiole | | | | |
| Total | 637.4 | 673.4 | 701.6 | 756.8 | 749.2 |
| Per cent increase in population | | 5.6 | 10.1 | 18.7 | 17.5 |

**Table 9.—The effect on the cotton aphid of applying Systox to the cut petiole of the sixth leaf of otherwise normal plant.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 48 | 72 |
| 1 | 127.8 | 118.8 | 76.6 | 50.8 | 36.4 |
| 2 | 154.2 | 130.8 | 94.4 | 16.2 | 2.6 |
| 3 | 149.4 | 92.4 | 36.2 | 13.0 | 0 |
| 4 | 112.4 | 38.6 | 1.8 | 0 | |
| 5 | 118.6 | 16.4 | 2.2 | 0 | |
| 6 | Systox applied to cut petiole[1] | | | | |
| Total | 662.4 | 397.0 | 211.2 | 80.0 | 39.0 |
| Per cent decrease in population | | 40.1 | 68.1 | 87.9 | 94.1 |

[1] Average amount of Systox absorbed was 1.9 c.c.

**Table 10.—Radioactivity shown in leaves of plants where radioactive Systox applied to cut petiole of sixth leaf.**

| Position of Leaf on Plant | Counts/Minute/Milligram | | |
|---|---|---|---|
| | Section Removed from Stem Between Fifth and Sixth Nodes | | Normal Plant |
| | Of Phloem | Of Xylem | |
| 1 | 6.55 | 0.09 | 0.63 |
| 2 | 1.56 | 0.04 | 0.99 |
| 3 | 31.48 | 0.04 | 12.17 |
| 4 | 42.61 | 0.05 | 53.95 |
| 5 | 24.01 | 0.05 | 25.51 |
| 6 | Radioactive Systox applied to cut petiole | | |
| No. c.c. Systox absorbed | 3.1 | 0.4 | 2.2 |

**Table 11.—The effect on the cotton aphid of Systox applied to the cut petiole of the fifth leaf with the petiole connected to the stem by xylem tissue only.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 36 | 48 |
| 1 | 134.8 | 121.4 | 70.2 | 20.4 | 0 |
| 2 | 146.8 | 94.6 | 8.6 | 0.2 | 0 |
| 3 | 134.0 | 48.4 | 2.0 | 0 | |
| 4 | 148.0 | 30.4 | 0.8 | 0 | |
| Total on leaves below site of application | 563.6 | 294.8 | 81.6 | 20.6 | 0 |
| Per cent decrease in population | | 47.7 | 85.5 | 96.3 | 100 |
| 5 | Systox applied to cut petiole[1] | | | | |
| 6 | 138.2 | 7.2 | 0 | | |
| 7 | 109.0 | 0.2 | 0 | | |
| 8 | 124.6 | 1.0 | 0 | | |
| 9 | 104.4 | 2.0 | 0 | | |
| Total on leaves above site of application | 476.2 | 10.4 | 0 | | |
| Per cent reduction of population | | 97.8 | 100 | | |

[1] Average amount of Systox absorbed was 2.68 c.c.

**Table 12.—The effect on the cotton aphid of Systox applied to the cut petiole of the fifth leaf with the petiole connected to the stem by phloem tissue only.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 36 | 48 |
| 1 | 127.6 | 132.0 | 134.6 | 132.8 | 239.0 |
| 2 | 99.8 | 107.2 | 107.4 | 115.2 | 193.0 |
| 3 | 156.8 | 168.6 | 177.8 | 183.2 | 211.0 |
| 4 | 142.4 | 155.0 | 165.2 | 180.4 | 314.0 |
| Total on leaves above site of application | 562.6 | 562.8 | 585.0 | 611.6 | 957.0 |
| Per cent increase in population | | 6.9 | 11.1 | 16.1 | 81.7 |
| 5 | Systox applied to cut petiole[1] | | | | |
| 6 | 115.4 | 125.2 | 132.0 | 143.2 | 305.0 |
| 7 | 97.2 | 105.4 | 114.2 | 126.2 | 132.0 |
| 8 | 102.6 | 118.2 | 128.4 | 118.8 | 161.0 |
| 9 | 72.0 | 81.8 | 87.2 | 94.8 | 56.0 |
| Total on leaves below site of application | 387.2 | 430.6 | 461.8 | 483.0 | 654.0 |
| Per cent increase in population | | 11.2 | 19.3 | 24.7 | 68.9 |

[1] Average amount of Systox absorbed was 0.32 c.c.

**Table 13.—The effect of separating phloem and xylem tissues at the fifth node on populations of the cotton aphid.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 36 | 48 |
| 1 | 102.0 | 99.2 | 101.2 | 106.0 | 188.0 |
| 2 | 88.4 | 97.0 | 106.0 | 98.8 | 3.0 |
| 3 | 113.0 | 126.2 | 136.6 | 134.6 | 216.0 |
| 4 | 96.0 | 88.6 | 89.0 | 90.0 | 184.0 |
| Total on leaves below point of separation | 399.4 | 411.0 | 432.8 | 429.4 | 591.0 |
| Per cent increase of population | | 2.9 | 8.4 | 7.5 | 48.0 |
| 5 | No systox applied to petiole | | | | |
| 6 | 98.8 | 101.8 | 100.2 | 93.4 | 134.0 |
| 7 | 88.4 | 99.6 | 105.0 | 114.0 | 202.0 |
| 8 | 100.6 | 115.8 | 125.4 | 132.4 | 182.0 |
| 9 | 77.0 | 82.6 | 96.0 | 89.6 | 84.0 |
| Total on leaves above point of separation | 364.8 | 399.8 | 426.6 | 429.4 | 602.0 |
| Per cent increase of population | | 9.6 | 16.9 | 17.7 | 65.0 |

Translocation of Systox in a downward direction also occurred but it proceeded much more slowly than in an upward direction. Complete kill of all aphids on the leaves below the site of application occurred in most cases within 72 hours. Absorption of about twice as much insecticide by the plants was required to give a complete kill when the translocation was downward instead of in an upward direction, tables 6 and 9. Movement of Systox proceeded in both directions in the xylem simultaneously. When the insecticide was applied through the cut petiole of a leaf located midway the plant complete kill of all aphids on the leaves above the site of application occurred within 24 hours but a period of 48 hours' exposure was required to kill all those below the site of application, tables 11 and 14.

**Table 14.—The effect on the cotton aphid of Systox applied to the cut petiole of the fifth leaf on otherwise normal plant.**

| Position of Leaf on Plant | Average Number Aphids per Leaf Alive After Hours Indicated | | | | |
|---|---|---|---|---|---|
| | 0 | 12 | 24 | 36 | 48 |
| 1 | 130.8 | 118.2 | 108.8 | 13.4 | 0 |
| 2 | 140.4 | 99.4 | 20.4 | 0 | |
| 3 | 122.8 | 56.4 | 7.0 | 0 | |
| 4 | 128.8 | 40.6 | 3.4 | 0 | |
| Total on leaves below site of application | 522.8 | 314.6 | 139.6 | 13.4 | 0 |
| Per cent reduction of population | | 39.8 | 73.3 | 97.4 | 100 |
| 5 | Systox applied to cut petiole[1] | | | | |
| 6 | 129.6 | 3.2 | 0 | | |
| 7 | 113.8 | 1.6 | 0 | | |
| 8 | 95.4 | 3.6 | 0 | | |
| 9 | 105.6 | 4.2 | 0 | | |
| Total on leaves above site of application | 444.4 | 12.6 | 0 | | |
| Per cent reduction of population | | 97.2 | 100.0 | | |

[1] Average amount of Systox absorbed was 1.76 c.c.

**Table 15.—Radioactivity shown in leaves of plants where radioactive Systox applied to the cut petiole of the fourth leaf.**

| Position Leaf on Plant | Counts/Minute/Milligram | | |
|---|---|---|---|
| | Leaf Petiole Connected to Stem | | |
| | By Xylem Only | By Phloem Only | Normal Plant |
| 1 | 20.69 | 0.07 | 38.11 |
| 2 | 12.23 | 0.00 | 41.95 |
| 3 | 18.71 | 0.01 | 21.08 |
| 4 | Systox applied to cut petiole | | |
| 5 | 27.83 | 0.00 | 27.29 |
| 6 | 42.12 | 0.08 | 115.81 |
| 7 | 44.93 | 0.09 | 116.20 |
| No. cc. Systox absorbed | 2.1 | 0.2 | 3.4 |

In previous work it was found that leaves having their blades submerged in Systox diluted 1:800 with water for 5 days abscissed. Discoloration was found in the vascular bundles of the petioles. Sections cut 15 microns thick from these petioles and stained with very dilute Delafield's Haemotoxylin showed the discoloration to be in the xylem tissues, figure 8, when compared with normal xylem tissues, figure 9.

Translocation of Systox through the phloem tissues was not observed. In all cases where the petiole through which the Systox was applied was attached to the stem only by tissues external to the xylem no kill of aphids was obtained. On the contrary, aphid populations increased, on the infested plants, tables 2, 7, and 12. Where plants were treated in this manner slight fluctuations in aphid populations were observed which may have resulted from an adverse effect on the plant resulting from cutting of the xylem tissues, table 8.

Comparable results were obtained where Systox tagged with sulfur[35] was used to study translocation of the insecticide, tables 5, 10, and 15.

Seed from fruit treated with Systox tagged with sulfur[35] contained measurable amounts of radioactivity 35 days after treatment at which time the seed was practically mature. Samples of seed taken from fruit 14, 21, and 28 days after treatment showed a gradual decline in amount of radioactivity. There was a slight increase in radioactivity of seeds taken from

**Table 16.—Transfer of Systox into cotton fruit at different stages of growth.**

| Part of Plant Analyzed | Counts per Minute per Milligram of Sample[1] | |
|---|---|---|
| | Treated When Blossom | Treated as a Boll One Day Prior to Time Sampled |
| Blossom | 4.56 | — |
| Leaf opposite blossom | 185.77 | — |
| Boll—7 days old | 7.07 | 2.40 |
| Leaf opposite boll 7 days old | 258.03 | 173.91 |
| Boll—14 days old | 2.99 | 1.74 |
| Seed from boll 14 days old | 2.25 | 1.71 |
| Bur from boll 14 days old | 2.50 | 1.69 |
| Leaf opposite boll 14 days old | 122.42 | 192.44 |
| Boll—21 days old | 1.98 | 0.91 |
| Seed from boll 21 days old | 1.92 | 0.66 |
| Bur from boll 21 days old | 2.36 | 1.27 |
| Leaf opposite boll 21 days old | 189.8 | 143.66 |
| Boll—28 days old | 1.62 | 0.78 |
| Seed from boll 28 days old | 1.18 | 0.49 |
| Bur from boll 28 days old | 1.56 | 0.95 |
| Leaf opposite boll 28 days old | 84.30 | 240.27 |
| Boll—35 days old | 1.77 | 0.96 |
| Seed from boll 35 days old | 1.38 | 0.54 |
| Bur from boll 35 days old | 2.20 | 1.30 |
| Leaf opposite boll 35 days old | 118.58 | 253.46 |

[1] Average of five replicates.

fruit 35 days after treatment when compared with samples taken 28 days after treatment. No explanation is offered for the slight increase shown at this time. The same gradual decrease in radioactivity was observed when samples of the boll and and bur alone were analyzed, table 16.

An inverse correlation was found between the age of bolls when Systox was applied and the amount of radioactivity at the time of analysis. Lower radioactivity was found in bolls treated 24 hours before sampling and sampled when 7, 14, 21, 28 and 35 days old than in bolls of the same age treated at flowering, table 16. This indicates that the material is concentrated in the more rapidly growing young tissues.

SUMMARY.—Translocation of Systox in the cotton plant was found to occur only in the xylem tissues. It moved in both directions simultaneously but movement in an upward direction was more rapid. Seed from fruit treated at flowering with Systox tagged with sulfur[35] showed measurable amounts of radioactivity 35 days after treatment with a progressive decrease during this period of time.

## LITERATURE CITED

**Curtis, O. F.** 1925. Studies on the tissues concerned in the transfer of solutes in plants. The effect on the upward transfer of solutes of cutting the xylem as compared with cutting of the phloem. Ann. Bot. **39:** 573–83.

**Mason, T. G.,** and E. J. Maskell. 1928. Studies on the transport of carbohydrates in the cotton plant. Ann. Bot. **42:** 189–253.

**Phillis, E.,** and T. G. Mason. 1940. The effect of ringing on the upward movement of solutes from the root. Ann. Bot. (n.s.) **4:** 635–44.

# Chemical Control of the Western Corn Rootworm in Kansas in 1953[1]

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The western corn rootworm, *Diabrotica virgifera* Lec., also called the Colorado corn rootworm was first reported injurious to corn in Kansas in Norton County in the summer of 1945 (Bryson *et al.* 1953). A distinct increase in population and damage by this insect occurred in Smith, Jewell, and Phillips counties in 1948 (Smith & Dean 1950). During the next 3 years, the population and subsequent injury to corn declined but began increasing again in 1952. This insect has caused severe losses to corn and was, without doubt, the most important economic insect pest of corn in many northern Kansas corn-growing counties during 1953.

The life history of this species is similar to that of the the corn rootworm, *Diabrotica longicornis* (Say) (Metcalf *et al.* 1951). Both species are effectively controlled by crop rotation and extensive studies on control were conducted by Hill *et al.*

[1] Contribution No. 622 Department of Entomology. Studies conducted under State Project 284. Thanks are due M. P. Breithaupt for his assistance in these studies.

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(1948) in Nebraska. Bigger (1932) found that the corn rootworm was not always successfully controlled when a field was removed from corn production for only one year. Numerous cases of this condition were observed by the author during 1953. In view of this fact, along with an existing increase in rootworm populations and because many farmers felt that rotation did not always fit into their plan, particularly under irrigated conditions, corn rootworm control plots were set up in Kansas in the spring of 1953. Although considerable work already had been conducted in Nebraska and Iowa, it was felt that additional experimentation was necessary under Kansas cultural practices and climatic conditions. Insecticide test plots were established in Jewell, Republic, Osborne, and McPherson counties to determine the most effective insecticide, the best rate of actual material per acre, as well as the most practical and economical method of application.

MATERIALS AND METHODS.—The insecticides used in these experiments included aldrin, BHC, chlordane, heptachlor, and lindane. Both emulsifiable concentrate and wettable powder formulations of these chlorinated hydrocarbons were used. Emulsifiable concentrates were used when spraying, while wettable powder formulations were used to mix with the starter fertilizers. A 20 per cent dust concentrate was used with the starter fertilizer in one field.

The tests included two general types of application, namely "broadcast" and "band or row" treatment. The broadcast application was one in which the insecticide was applied to the surface of the soil with a regular boom-type weed sprayer shortly before the corn was planted. These chemicals were then worked into the soil immediately after application to avoid loss of effectiveness.

The band or row type of treatment was subdivided into two different procedures. In one case the insecticides were applied as a spray from a lister mounted sprayer[3] which dispersed the solution through nozzles just behind the planter shoes (subsoilers) and in front of the cover disks and press wheels. The emulsifiable concentrate formulations were mixed with water and applied at the rate of approximately 3 gallons of solution per acre when driving approximately 3.5 miles per hour and maintaining a pressure of 30 pounds per square inch. A *TeeJet* nozzle[4] providing a flat fan-shaped spray pattern was employed. Height of nozzle was adjusted to result in approximately an 8-inch treated band on each row.

The second type of band or row treatment consisted of using wettable powder formulations of insecticides in proper amounts and mixing them thoroughly with enough starter fertilizer (0–45–0) to be applied at the rate of 80 pounds of fertilizer per acre. These starter fertilizer-insecticide mixes were applied through a planter fertilizer attachment at planting time.

Insecticide dosages included a 25 per cent wettable powder of aldrin, heptachlor and lindane each at 0.25 and 0.5 pound of actual toxicant per acre, a 50 per cent wettable powder chlordane at 0.5 and 1 pound of actual chlordane per acre, a 25 per cent emulsifiable concentrate of aldrin and heptachlor each at the rate of 0.5 pound of actual toxicant per acre, and a 75 per cent emulsifiable concentrate of chlordane at 0.75 pound of actual chlordane per acre. These insecticides were applied at the rates indicated, as a band treatment. Chemicals used for broadcast included a 75 per cent emulsifiable concentrate (e.c.) of chlordane at 1.5 pounds of actual chlordane per acre and BHC (11 per cent e.c.) at 0.5 pound of the gamma isomer per acre.

BAND TREATMENTS.—*Belleville plots (Republic County).* This field had been in corn for the 2 years previous to establishing the experiment, which consisted of eight treatments and one control each replicated three times. Heptachlor, aldrin, and lindane were each used at the rate of 0.25 and 0.5 pound of actual toxicant per acre and chlordane was used at the rate of 0.5 and 1 pound of actual toxicant per acre. Wettable powder formulations of these insecticides were carefully weighed for each plot and mixed thoroughly with the starter fertilizer applied at planting time (May 12). The control plots of all three replications were planted first and starter fertilizer applied. Each plot consisted of .05 acre.

*Formoso plots (Jewell County).*—Aldrin,

[3] A planter sprayer Model CP-2, manufactured by the Broyhill Company of Dakota City, Nebraska, and Sioux City, Iowa, and furnished by the company, was used in these experiments.

[4] Spraying Systems Tee-Jet nozzle No. ¼TT730077—100 mesh screen.

chlordane, and heptachlor were applied at the rate of 0.5, 0.75, and 0.5 pound of actual toxicant per acre, respectively, to plots each 0.25 acre in size with a lister-mounted sprayer at planting time.

*Lindsborg plots (McPherson County).*—A 20 per cent aldrin dust concentrate and a 25 per cent wettable powder formulation of heptachlor, each applied at the rate of 0.5 pound of actual toxicant per acre, were the only insecticides used in these plots. The chemicals were thoroughly mixed with a starter fertilizer and applied at planting time. Each plot was 1 acre in size, nonreplicated and under irrigation. The plot primarily was established for the control of the western species but later data showed the southern species to be the predominant one.

BROADCAST TREATMENT.—*Downs plots (Osborne County).*—Chlordane (75 per cent emulsifiable concentrate) and BHC (11 per cent e.c.) were applied at the rate of 1.5 pounds, and 0.5 pound gamma isomer per acre, respectively. These materials were applied as a preplanting treatment being broadcast or sprayed over the surface of the field before planting and plowed to a depth of about 7 inches. The remainder of the field, with the exception of a control plot, was treated with an aldrin and fertilizer (20–20–0) mixture and applied through a fertilizer attachment at planting time.

Results of all treatments were measured by several criteria. In early July, five plants were dug from each plot and the soil within a radius of 6 inches and to a depth of 8 inches was carefully examined for larvae, pupae, and newly emerged adults. At this same time, the root systems of 100 plants were examined in each plot. Lodging records were taken during mid-summer. Lodging in this paper refers to any corn plant deflected 25 degrees or more from the vertical position. Yield data were taken on the Belleville and Formoso plots in the fall.

RESULTS.—*Band treatments.—Belleville plots.*—On June 2, all plants in each of the plots were counted giving a total of 6070 plants. Using plant emergence as a criterion, these data were then subjected to an analysis of variance which showed no significant effects on germination between treatments.

Observations on the extent of root injury by corn rootworms (predominantly the western species) were made on July 10. One hundred plants were examined in each plot and the results are summarized in table 1. Although only 10 per cent of the plants were lodged in the control or check plot, it was significantly higher than any lodging found in the treated plots. Heptachlor, chlordane, and aldrin plots showed no lodging as compared with 2 per cent lodging in one of the lindane plots. A minimum of five plants was examined in each plot and the average number of larvae per plant is shown in table 1. It should be noted that the control plot had an average of 29.5 larvae per plant, which was considerably higher than any of the treated plots. The aldrin plots, though they showed no plants lodged, had the second highest number of larvae with an average of 9 and 13 per hill.

**Table 1.—Plants lodged, larvae per plant, and yields in the Belleville corn rootworm test plots, Republic County, Kansas, 1953.**

| TOXICANT[1] AND POUNDS PER ACRE | PLANTS LODGED[2] | | LARVAE PER PLANT[3] | YIELD (BU. PER ACRE)[4] |
|---|---|---|---|---|
| | July 10 | July 24 | | |
| Control (untreated) | 10 | 158[5] | 29.5 | 30 |
| Heptachlor, 0.25 | 0 | 0 | 3 | 32 |
| Heptachlor, 0.5 | 0 | 1 | 3 | 32 |
| Chlordane, 0.5 | 0 | 1 | 2 | 26 |
| Chlordane, 1 | 0 | 2 | 0 | 30 |
| Aldrin, 0.25 | 0 | 2 | 9 | 36 |
| Aldrin, 0.5 | 0 | 1 | 13 | 32 |
| Lindane, 0.25 | 0 | 5 | 3 | 30 |
| Lindane, 0.5 | 2 | 9 | 0 | 32 |

[1] Applied as a starter fertilizer-insecticide mixture at planting time.
[2] One hundred plants examined in each treatment.
[3] Average of five plants.
[4] Total plot harvest in three replications, Oct. 5–6.
[5] A total of 336 untreated plants were examined.

On July 24, lodging records were taken a second time by examining 100 plants in each plot and the results are included in table 1. It can be seen that the heptachlor, chlordane, and aldrin treated plots produced similar results in reduction of lodging with no outstanding differences between the higher and the lower rate of application. The lindane plots displayed a higher percentage of lodging (5–9 per cent) than other treated plots. However, approximately 47 per cent of the plants in the control or check was lodged. In a nearby untreated plot of corn, variety K1859, 52 per cent of the plants showed lodging.

Additional plants were dug on July 24, to learn more about the development of the corn rootworm, as shown in table 2. In order to avoid undue sacrifice of plants, and because of the time consuming task

**Table 2.—Larvae and pupae recovered from two plants in each of the nine plots at Belleville, Kansas, July 24, 1953.**

| Toxicant and Pounds per Acre | Number of Larvae | Number of Pupae | Total | Per Cent Pupation[1] |
|---|---|---|---|---|
| Control | 12 | 31 | 43 | 72 |
| Heptachlor, 0.25 | 5 | 2 | 7 | 28 |
| Heptachlor, 0.5 | 5 | 1 | 6 | 16 |
| Chlordane, 0.5 | 1 | 0 | 1 | 0 |
| Chlordane, 1 | 3 | 1 | 4 | 25 |
| Aldrin, 0.25 | 9 | 4 | 13 | 30 |
| Aldrin, 0.5 | 8 | 2 | 10 | 20 |
| Lindane, 0.25 | 2 | 1 | 3 | 33 |
| Lindane, 0.5 | 2 | 1 | 3 | 33 |

[1] Calculated from the number of larvae and pupae found in the soil on July 24. It was obvious that many beetles had already emerged as evidenced by their presence on the plants.

involved, the sampling in this case was limited to two plants. Although such a sample is inadequate for statistical analysis, it does provide an indication. Data from table 2 show 72 per cent pupation in the control plots on July 24, as compared with an average of only 23 per cent in all of the treated plots. Thus it appears that the development of the larvae surviving the treated plots had been retarded as a result of being in contact with the insecticides. If this is true, such a phenomenon could be of importance in that much corn, particularly that planted fairly early, could be already pollinated before the beetles appear on the silks. Furthermore, the reduction in number of beetles, as shown in table 2, would in itself be a factor in reduction in pollination loss. Larvae from the roots and soil of plants from treated plots were brought to Manhattan and placed on potted corn plants in clean soil to be reared, but the experiment was unsuccessful.

Data obtained by digging numerous plants on July 28, indicated that emergence of beetles was virtually complete on that date. Subsequent observations on adults showed that practically 99 per cent of the corn rootworms consisted of the western or Colorado species. An interesting and perhaps an important observation was made on July 30 concerning adult populations in the insecticide test plots. Control and treated plots were randomized in each of three replications. Beetles were present in large numbers on the plants in the control plots and virtually absent from any of the surrounding treated plots. This would seem to indicate that there might not be any extensive migration of adults from untreated to nearby treated areas. Other observations, however, show a migration of beetles for at least 0.25 mile.

On August 20, a single plant was taken at random in each plot. The root systems and ears of these plants are shown in figure 1. No marked differences appear in root systems and ears among treatments, although there was a distinctive difference between the control plant and the treated plants.

Yield data were taken on October 5 and 6 when the entire plots were harvested by hand (Table 1). There was no highly contrasting difference in yields between the treatments and the controls although the treatments averaged slightly more than 1 bushel per acre higher than the controls. Similar results were reported by Hill *et al.* (1948) and Cox & Lilly (1953). In the Belleville plots, there was no appreciable loss in yield resulting from clipping of silks by the beetles. It appeared that the plots were planted early enough so that pollination had already occurred before large populations of beetles appeared.

*Formoso plots.*—Observations were recorded on 100 plants in each plot as shown in table 3. The western corn rootworm was by far the predominant species in the Formoso area. Larvae, pupae, and adults were found on July 9. It was estimated that approximately one-fourth of the population already existed as beetles and that one-third of the life stages of this insect remaining in the soil were pupae. Lodging differences between treated and untreated plots were rather distinct. The treated plots showed an average of 0.33 per cent lodging as compared with an average of 29 per cent in the controls. Hills examined in the chlordane plot contained more larvae than those taken from plots treated with either aldrin or heptachlor.

**Table 3.—Plants lodged and larvae per plant and yields in the Formoso corn rootworm test plots, Jewell County, Kansas, 1953.**

| Toxicant and Pounds per Acre | Plants Lodged[1] July 9 | Larvae per Plant[2] | Yield of Ear Corn | |
|---|---|---|---|---|
| | | | Bushels per Acre | Per Cent Increase |
| Control, No. 1 | 35 | 72 | 4.1 | — |
| Control, No. 2 | 22 | 84 | | — |
| Control, No. 3 (K1859) | 30 | 72 | | — |
| Aldrin, 0.5 | 1 | 2 | 10.0 | 150 |
| Chlordane, 0.75 | 0 | 14 | 8.6 | 114 |
| Heptachlor, 0.5 | 0 | 1 | 7.4[3] | 86 |

[1] One hundred plants examined in each treatment.
[2] Average of five plants.
[3] Yield reduced by a large number of beetles that moved in from the adjacent remainder of the field and clipped enough silks to cause a reduction in pollination.

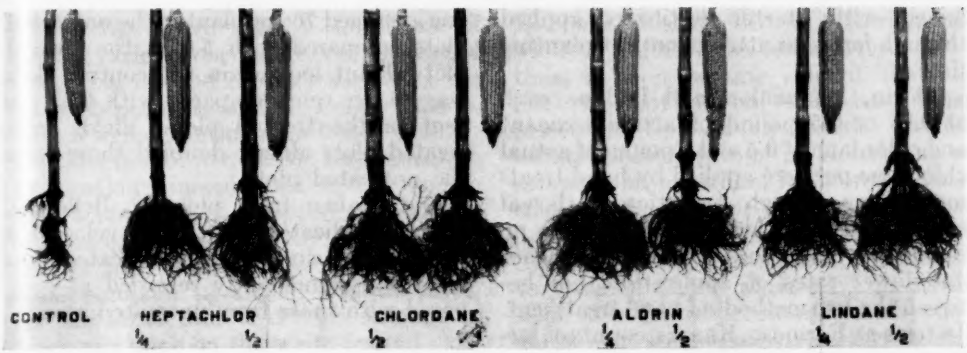


FIG. 1.—Root systems and ears of corn plants taken at random from each of the Belleville plots on August 20, 1953. Numerals indicate dosages of each of the toxicants applied per acre.

The test plots at Formoso were harvested October 2 and 3 and the results are summarized in table 3.

Much of the reduction in yield at the Formoso plots was caused by beetle injury to silks, which prevented pollination. There were no outstanding differences among the treatments but highly contrasting differences existed between the control and the treatments.

Comparative yields were taken from fields adjacent to the Formoso plots. One field had been in corn continuously for 3 years, had serious corn rootworm damage, and yielded 4.1 bushels per acre while the other had not been in corn during the previous 3 years, had no rootworm damage, and yielded 27.7 bushels per acre, a gain of 574 per cent. These differences are highly significant.

*Lindsborg plots.*—Only lodging records and larval and pupal counts were taken on these plots. Two hills were dug in each plot with a total of 1 and 0 larvae being found in the aldrin- and heptachlor-treated plots, respectively, as compared with a total of 16 (6 larvae and 10 pupae) in the control plot. On July 21, 100 plants in each plot were examined for lodging with the following results: aldrin, 1; heptachlor, 0; untreated, 14. Lodging records taken in late September showed results similar to those taken on July 21.

*Downs plots.*—Records on plant lodging and counts of larvae per hill were taken on July 9. The corn was in the whorl stage and adults were already present in small numbers. Again the western corn rootworm was the predominant species.

Since a misunderstanding resulted and the insecticides used in these tests were plowed under deeply after application instead of being disked in lightly as planned, it is not surprising that irregular and insignificant results were obtained. The controls showed 11 per cent lodging as compared with an average of 14 per cent in the treated plots, but there were an average of 12 larvae per plant in the untreated plots compared with an average of seven per treated plant.

The matter of a broadcast type of application previous to planting time where corn is listed rather than surface planted needs considerable additional experimentation. From this experiment, and more especially from reports from several farmers, the efficiency of this method for the control of corn rootworms seems questionable in an agricultural area where virtually all corn is listed.

SUMMARY.—Experiments conducted primarily for control of the western corn rootworm, *Diabrotica virgifera* Lec., with aldrin, BHC, chlordane, heptachlor, and lindane gave promising results. Emulsifiable concentrations were used when applications were made by spraying; otherwise wettable powders were used to mix with starter fertilizers with the exception of a 20 per cent dust concentrate of aldrin in one field.

Broadcast applications consisted of applying the insecticides to the surface of the soil previous to planting with a boom-type weed sprayer and working the chemicals into the soil immediately after application to avoid loss of effectiveness. In band or row type applications, the insecticides were applied either as a spray from a lister-mounted sprayer, or by use of wettable powder formulations of insecticides

mixed with starter fertilizers applied through fertilizer attachments at planting time.

Aldrin, heptachlor, and lindane each at 0.25 or 0.5 pound of actual toxicant and chlordane at 0.5 and 1 pound of actual chlordane per acre applied by band treatment gave a high reduction in larval counts and plant lodging. There were no important differences between the higher and lower rates of application, nor between the two methods of band treatment. In tests at Formoso, Kansas, counts of larvae averaged 76 per plant in the untreated plots compared with 5.6 in the treated plots. Plant lodging in the control plots was 29 per cent compared with 0.33 per cent in the treated plots. Yields from treated plots almost doubled those from the untreated plots.

Data taken from plots at Belleville, Kansas, indicated that the development of the larvae surviving in the treated plots had been significantly retarded as compared with those from untreated areas.

## LITERATURE CITED

**Bigger, J. H.** 1932. Short rotation fails to prevent attack of *Diabrotica longicornis* Say. JOUR. ECON. ENT. 25(2): 196–9.

**Bryson, Harry R.,** Donald A. Wilbur and C. C. Burkhardt. 1953. The western corn rootworm, *Diabrotica virgifera* Lec. in Kansas. JOUR. ECON. ENT. 46(6): 995–9.

**Cox, H. C.,** and J. H. Lilly. 1953. Chemical control of the corn rootworm. JOUR. ECON. ENT. 46(2): 217–24.

**Hill, R. E.,** E. Hixson and M. H. Muma. 1948. Corn rootworm control tests with benzene hexachloride, DDT, nitrogen fertilizers, and crop rotations. JOUR. ECON. ENT. 41(3): 392–401.

**Metcalf, C. L.,** W. P. Flint and R. L. Metcalf. 1951. Destructive and useful insects. 3rd ed. McGraw-Hill Book Company, New York, New York.

**Smith, Roger C.,** and Geo. A. Dean. 1950. The eighteenth or 1948 annual insects population summary of Kansas. Jour. Kans. Ent. Soc. 23(1): 9.

# Biological Control of Cactus in Hawaii[1]

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This paper is an account of the work done since 1943, under the direction of the Board of Agriculture and Forestry of the Territory of Hawaii, to suppress the tree cactus, *Opuntia megacantha*, on the island of Hawaii. On certain large grazing areas, the plant has, in the past 50 years, increased and spread at an alarming rate, covering the lower lands almost solidly in many areas, whilst consistently pushing forward into the upper and better pastures. Attention was drawn to this menace as early as 1930 by A. W. Carter, manager of the Parker Ranch. In the previous quarter century this ranch had been brought to high productivity by establishing a pure-bred herd, introducing a complete water system, fencing, sowing imported seed of the best grasses and other forage crops, and judicious suppression of weeds. But the mechanical destruction of cactus appeared to be too costly an undertaking, under the circumstances of those days; and hearing of the great success of the Australian government in attacking their cactus problem by the biological method, he turned to the local government agency, the Board of Agriculture and Forestry, of which he was originally a member, to give financial support and assistance in bringing about similar results, if it considered the same feasible. It is believed that the Board of Agriculture and Forestry would have done this had not violent opposition to such a procedure arisen from ranchers occupying lands poorly supplied with water, feed and high-class animals, where the cactus was considered an asset in times of drought. It took years to overcome this opposition, but eventually this was accomplished, at least as far as the island of Hawaii was concerned, since many of the poorer ranches were able to develop water, and the incidence of disease in the desirable red-fruited cactus led to the loss of this plant on ranches located on the islands of Kauai, Niihau, Oahu, Molokai, and Maui. Meanwhile the concern of the Parker Ranch management over the invasion of the cactus into its best pastures became so great that they were willing to grasp at almost any expedient to block the spread in these areas; and so a joint project to ef-

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fect cactus destruction by the disease of the red variety was undertaken, the Board of Agriculture and Forestry supplying the spore-suspensions and the Parker Ranch, with a well-organized crew working under the direction of Mr. H. W. Baybrook, began making inoculations to accomplish this; a tank-wagon equipped with four to six hoselines, and specially heavy needle outlets was used, the flow of suspension being regulated by a hand-pressure valve. At the same time a certain amount of work was done on the white-fruited variety of cactus by the same crew using ordinary spraying equipment. This effort was continued as late as 1949.

INSECT STUDIES.—The Board of Agriculture and Forestry was fortunate at the time the employment of insects was under consideration to secure the interest of Professor Harry S. Smith, of the Department of Biological Control, University of California, who was visiting the islands at frequent intervals in conjunction with his responsibilities as a member of the Pacific Science Board and in the direction of the oriental fruit fly research effort by University of California workers. Professor Smith, who had done considerable work on insect control of Opuntia on the Santa Barbara Channel islands of California, offered to supply us with cactus insects from California and also to help us contact workers at the Texas Agricultural Experiment Station, Winter Haven,[2] who had cooperated with the Australian collectors. Through this second contact we were able to secure certain additional species of cactus insects.

*California Cochineal.*—With the adoption of the cactus insect introduction program by the Board of Agriculture and Forestry, Mr. Philip Weber was authorized to go to Riverside, California, and collect insects with Professor Smith's cooperation and to conduct starvation tests with these insects on the main economic plants of Hawaii. At the same time the writer was assigned the responsibility of receiving and processing any shipment of specific Opuntia-feeding insects that might be sent to Hawaii. The first insect to be shipped was the California cochineal collected at Pomona. A total of 53 shipments of this insect comprising 200,000 specimens were made during the months of January, February, March, and April of 1949. These specimens were placed on rooted cuttings of *Opuntia megacantha* at Kamuela, Kohala district, Hawaii, and while a limited number survived for a time, it soon became evident that the insect was not adapted to this host. When placed on *Opuntia cordobensis*, another cactus species growing in Kohala, as an escape from a garden, it showed greater adaptability, but due to the predation of carnivorous ants, it eventually failed even there. This disappointment, coming at the very outset of the work, gave us an insight into the rather complicated procedures and techniques necessary to succeed in the biological control of weeds, and we began to realize we would have numerous obstacles to overcome before we could expect to make progress in the control of Opuntia.

*Coreids and Mealybugs.*—At the end of May, 1949, the work on the receiving end of the cactus insect introductions was transferred to the Board of Agriculture and Forestry facilities in Honolulu, since those at Kamuela, Hawaii, were not satisfactory. The next insects to be tried were the Coreids, *Chelinidea* spp. On June 8th a shipment of Chelinidea bugs including examples of two species, *tabulata* and *vittiger*, was received from Mr. Weber at Riverside, and these were placed on potted tree-cactus plants and selected economic plants of Hawaii. The bugs deposited eggs on *O. megacantha* and nymphs developed to the 3rd stage. However, when the nymphs caged on pineapple plants produced feeding scars on the leaves, it was decided not to attempt establishment of the bugs and the entire lot was destroyed. In the meantime Professor Smith had the opportunity to visit Australia and learned that the California cochineal was not the same species as the cochineal attacking the tree cactus in that country. This latter species had been obtained in Mexico and became established in Australia on *Opuntia streptacantha*, a tree cactus closely allied to *O. megacantha*. It was therefore decided that shipments of this cochineal, the mealybug, *Dactylopius opuntiae*, should be requested from the Australian entomologists. Consequently, on the 29th of June 1949 ten pads of *Opuntia streptacantha* heavily infested with Mexican cochineal, i.e., mature clumps of *Dactylopius opuntiae* were received in Honolulu. Transfers were made to *Opuntia*

[2] This cooperation was largely furnished by Mr. E. Mortensen, whose kindness is here most gratefully acknowledged.

*megacantha* plants established from cuttings of both the red and white-fruited varieties and in a short time many flourishing colonies of the mealybug were observed. Starvation tests were conducted with economic plants and in due course this insect was approved for use on the island of Hawaii (August, 1949) and infested plants were taken to the Parker Ranch where the mealybugs were successfully cultured at a station several miles above Kawaihae and close to the government road, and from whence infested pads were distributed over the entire Parker Ranch. The crawlers of this mealybug are wind disseminated and have already been spread 2 to 5 miles from colonization points by this agency.

*Lepidoptera.*—In the fall of 1949, shipments of the eggs of two species of Lepidoptera *Melitara prodenialis* and *M. doddalis* were received from Texas. In September, 1949, five lots of 1000 eggs each, of *prodenialis*, collected along the Gulf Coast at Palacios, were received, and in October two additional lots were received. In October four lots of 2000 to 4000 eggs of *M. doddalis*, a species found in Western Texas, were received, and in November three lots were received. These eggs hatched in due course and the larvae were reared on *O. megacantha* cuttings. Starvation tests were made on economic plants and the insects were eventually cleared for liberation. There was considerable disease amongst the caterpillars but some were reared through. Part of this material was sent to Hawaii and field liberations were made but apparently the species were not adapted to our conditions and eventually disappeared.

*Cactoblastis cactorum.*—Mr. Alan Dodd, the Australian authority on the cactus insects, on being advised of the unstaisfactory results attending the introduction of the Texas insects, recommended our trying analogous species which had succeeded best in Australia. It was therefore decided to bring in *Cactoblastis cactorum*, the moth borer from Uruguay, which had produced such phenomenal results in Queensland. Accordingly, eggs of this species were officially requested and the first shipment, comprising 4200 eggs, arrived February 6th, 1950. Hatching began on the 9th of February and a brood was reared on potted cactus plants. Pupation began March 16th and the first moths emerged April 6th. Starvation tests on economic plants were made and the tests completed by the end of April. Subsequently the insect was cleared for release and 139 egg-sticks (a chain of eggs built out from a cactus spine by successive depositions) comprising 5,850 eggs, were obtained from oviposition cages and sent to the Parker Ranch for placement in the field. Most of these egg-sticks were placed on plants at Puupelu and a few were taken to Kawaihae. Later, an additional shipment of over 200,000 eggs was received from Mr. Dodd at Brisbane and sent to the Ranch for placement on field cactus. 190,000 were put on cactus in the vicinity of the Kolea water-trough, on the Range, and 11,000 on cactus in the Puuhine tree plat above the Kona Road. At the completion of larval development the worms descend to the ground and pupate in the low herbage around the cactus. Cocoons of these numbering 37,638 were collected in the field where the above-stated liberations had been made. These were brought in and placed in 11 oviposition cages. Moths emerged and deposited eggs from April 1st to June 26th, 1951, the number of eggs collected from these cages totaling 1,451,549. Eggs collected in the field were estimated to number 60,000. Three hundred thousand of these (2nd generation) were again distributed in the field at Kolea. Eggs were also placed in lots of 10,000 to 20,000 in four localities on the Range, at Nahonohae in three places, at Puuhine I at four places, at Puuhine II at three places, at Big Heewai at four places, at Puukawaiwai at 12 places, in Kohala at two places, and in Kawaihae-uka II in four places. Three thousand cocoons were placed in a control cage. Eggs collected in this cage numbered 132,138. Average egg-deposition per female moth was estimated at 91. According to Mr. H. W. Baybrook, who had charge of this rearing and distribution, thus far carnivorous ants appear to be the only serious predator, as they destroy all eggs they can find. Some eggs are parasitized by Trichogramma (*T. minutum* Riley). The praying mantis also will feed voraciously on the larvae of each instar. At Kolea, where the cocoons of each brood are collected for holding to secure eggs after moth emergence and mating, all cactus trunks are greased before placing eggs on the plants, to keep ants away from them. No protection was given eggs in

other areas, resulting in a 30 per cent loss. This loss can be reduced to 10 per cent by holding the eggs until they begin to hatch, before placing in the field.

*Cactoblastis* has succeeded far beyond our expectation and today is present by the millions on the Parker Ranch lands. It develops on both the red-fruited and the white-fruited varieties of *Opuntia megacantha*, and a seedling plant that becomes infested will be eaten to the ground. Roughly two broods a year can be counted on, and the species flourishes from sea-level to the 4000-foot elevation. It is judged that several years will be required to determine its capacity for cactus destruction. However, in one area on the Ranch, it has been evident for some time that the combined effect of the cochineal and *Cactoblastis* is devastating, so many large plants have been destroyed that the acreage is now suitable for sowing to Guinea grass.

*Beetle-borers.*—In April, also, the Texan beetle-borers *Moneilema armata* and *M. crassa* (Cerambycidae) began to emerge, and Mr. Mortensen kindly undertook to collect and ship them to Honolulu for trial. On the 20th of April the first shipment, containing 24 beetles, was received, and in May there were five additional shipments, containing more than 500 beetles. These beetles were placed on cactus cuttings in a wire-screen cage. The first eggs were observed on the 8th of May. The larvae seemed to develop normally in the *megacantha* cactus and tests were made in the same cages to determine if they would develop in any of our economic plants, or whether injury would result to any of these plants from the adults searching for food and oviposition places. However, neither injury nor development was observed in these plants and release of the beetle was therefore authorized. With this authorization, 400 surviving beetles and plants with eggs and larvae and about 500 loose eggs deposited on the floor and sides of the cage were taken to the Parker Ranch and placed in the Laelae and Lalamilo pastures near clumps of cactus, the grubs from the loose eggs upon hatching being transferred to plants in which incisions had been made to facilitate entrance to the tissues.

As with the *Melitara* substitution, Dodd's recommendation was to change over from *Moneilema* to the Australian-acclimatized, Central-American species of beetle-borer *Lagocheirus funestus*, and this was done as soon as *Lagocheirus* became available, which was in the fall of the year (Australian spring) or the month of November; but in the meantime two shipments of Moneilema beetles consisting of 133 males and females were received from Texas in September and two shipments in October including 63 beetles as well as an additional 2,000 eggs of *Melitara*. All of this material was sent to the Parker Ranch for field release.

The first *Lagocheirus funestus* shipment was received on the 26th of November 1950 in two cartons and consisted of 31 adult beetles and 270 cocoons. Emergence from the cocoons occurred between December 3rd, 1950 and January 15th, 1951, yielding 174 beetles, which, together with those that came as adults, totaled 205 beetles. These were placed in the same cage with *Moneilema*, the cage being well stocked with cactus cuttings and supplied with Hawaiian economic plants. As the adults possess distinguishing characters to mark the sex, a sample lot comprising 56 beetles was sexed and it was noted there was a 2 to 1 ratio, males predominating. No attention was paid by the beetles to any of the economic plants but oviposition began almost at once in the cactus logs (this beetle prefers to work in the woody stems), the oviposition scars appearing as a crosspatch of furrows. With the hatching of the eggs and boring of the larvae, which are to some extent gregarious in their attack upon the tissues of the plant, the cactus slabs soon showed signs of collapse, soft rots, following the tunnelling, contributing a large share to the tissue destruction. Some of these hollow stems were broken into, and while larvae were generally encountered, eventually cocoons were found, most frequently at or near the joint. The first cocoon was observed March 6th, indicating that about 100 days were required for development from egg to pupa at this season of the year. On April 19th the first adult was observed, fixing the pupal period at 44 days. Combining these records gives a developmental period of 144 days, nearly 5 months, and later records indicate that more than one full brood yearly cannot be expected, the heaviest emergence of adults coming in the middle of summer (June-August).

In the meantime the insect had been

cleared for release, and on June 16th 100 cocoons and unopened logs containing developing larvae estimated at 100 were sent to the Parker Ranch. On June 21st, an additional 105 cocoons were sent. At this point it should also be recorded that in July 1951 six additional shipments of the *Moneilema* beetles were received, comprising 429 males and females, which were liberated in the Laelae pasture on the Parker Ranch. Resuming with *Lagocheirus*, by the 15th of August 120 beetles had emerged from their cocoons. These were first placed in cages with cactus logs, 17 cages being thus stocked, and oviposition and larval development proceeded with such vigor that after the lapse of a few weeks, a large number of the adults and larvae were removed from the cages and taken to the field, where the larvae were placed into standing cactus, an entrance hole being provided mechanically, the adults also being liberated in the immediate vicinity. These releases were made, one above the Kohala Road on the edge of the Laelae pasture and partially in the gulch where there is a stand of very old cactus; and another, below the road and nearer the Kawaihae-uka pastures. At Honolulu, the cages were cleared and re-stocked. Additional shipments comprising 62 beetles were made to the Ranch as follows: on Aug. 13th, 24 beetles; Aug. 20th, 26 beetles; and Sept. 1, 12 beetles. On Sept. 15th, 1951, a second shipment of cocoons was received from Brisbane, Australia, containing 200 cocoons. Adult emergence began October 13th and continued until the end of the year. These beetles were placed temporarily in the Board cages and shipments made to the Ranch from time to time as follows: on Oct. 30th, 50; Nov. 2nd, 50; Nov. 6th, 50 Nov. 14th, 52; Nov. 27th, 50; Dec. 5th, 50; Dec. 13th, 50; Jan. 2nd, 1952, 50; Jan. 22nd, 25. Altogether 499 beetles were sent in these shipments. It is believed that most of these beetles were liberated in the field at the points indicated above. The new generation began emerging in the Board cages at the end of January, 1952; and cocoons were again collected from one of the cages. Emergence continued through the first 6 months of 1952 and an additional 85 adults were sent to the Ranch. At the same time emergence from cage placements made in June, 1951, was reported from the Parker Ranch and these adults will be either liberated or permitted to oviposit on cactus logs in the 17 or more cages provided for this purpose, and later liberated. There is every indication at the time of the present writing that *Lagocheirus* will succeed, although its increase may proceed at a much slower pace than with the other two cactus insects.

SUMMARY.—Suppression of the tree cactus, *Opuntia megacantha*, has been under way in the best pasture areas on the island of Hawaii since 1943. Destruction by the disease of the red-fruited cactus was unsuccessful.

Several species of insects which attack *Opuntia* were introduced from California, Texas, and Australia. With *Cactoblastis cactorum* and *Dactylopius opuntiae* definitely established and on the increase, biological control of *Opuntia* spp. on the island of Hawaii appears most promising.

# SCIENTIFIC NOTES

## Self-Treatment Rubbing Devices for Louse Control on Cattle

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Control of cattle lice by dipping or spraying is often neglected or purposely omitted during the winter because of adverse weather. It is during this period, however, that the lice become most numerous and do the most damage.

In view of these conditions it was thought that a simple method of self-application of an insecticide in oil might be acceptable. Rogoff & Moxon (1952) have described such a self-treatment device used in South Dakota for horn fly control, and Lindquist & Hoffman (1954) have reported on similar units used in Oregon.

The rubbing devices used in these tests differed from those used in the horn fly studies only in the manner of suspending the burlap-wrapped cable or barbed wire. In the horn fly tests the wire was loosely suspended between two posts to form an arc. In the present tests the rubbing units had a single center pole to which the wire was attached at a height of approximately 5 feet and then fastened near the ground to two securely set posts at distances of 9 feet on opposite sides of the center pole. The strands of barbed wire (four to six, depending on the size of the cattle) were twisted together until taut, and then wrapped with burlap sacking. The taut wire allowed the animals to put greater pressure on the unit and thus to get the insecticide on the part of the hide where the lice persist. The angle of the wire made it easier for the animals to rub any part of their bodies. Animals were even observed straddling the wire and rubbing between their legs.

Of nine self-treatment rubbing devices established for control of cattle lice during the winter of 1952–53, six were with herds of Hereford, two with Holstein, and one with Holstein and Jersey cattle. Four of the herds were in the cold, dry area of eastern Oregon and five in the wet climate of the Willamette Valley. All the cattle were confined to feed lots or small pastures, as is the common practice in those areas during the winter. The average herd contained 40 head of cattle; the maximum number in one herd was 75.

Only one chemical was used in the tests, in order that sufficient replications could be made with a minimum number of units. Chlordane was selected as it had given satisfactory control of horn flies with rubbing devices (Lindquist & Hoffman 1954), and chlordane is also among the more effective sprays for louse control. One gallon of 5-per cent chlordane in No. 2 fuel oil was poured over the sacking of each unit as the initial application, and after approximately 30 days a second treatment of 2 quarts was applied.

Two species of cattle lice, *Bovicola bovis* (L.) and *Linognathus vituli* (L.), were present in varying proportions on the different herds, the latter being the more common. Estimates of louse populations on the animals were obtained by counting the lice in ten 1-inch squares—one each on the poll, shoulders, lower neck, and dewlap, two along the back, one at the base of the tail, one on the hind quarters, and two in the lateral abdominal region. Counting was facilitated by use of a cardboard having holes 1 inch square, so that judging the size of the counting area was unnecessary. It is recognized, however, that the counting method is a rough estimate at best.

**Table 1.—Control of cattle lice with a self-treatment rubbing device containing chlordane.**

| Cattle Breed | Herd | Average Number of Lice per Square Inch Before Treatment | Per Cent Reduction of Lice After— | |
|---|---|---|---|---|
| | | | 15 Days | 22–25 Days |
| Holstein and Jersey | 1 | 4.3 | 91 | 100 |
| Holstein (calves) | 2 | 2.5 | — | 96 |
| | 3 | 1.9 | 89 | 100 |
| Hereford Yearlings | 4 | 1.8 | — | 100 |
| | 5 | 1.8 | — | 99 |
| | 6 | 2.1 | — | 100 |
| Cows and bulls | 7 | 2.1 | — | 100 |
| Cows and steers | 8 | 4.5 | 89 | — |
| Calves and yearlings | 9 | 5.6 | 91 | — |
| Holstein (check) | 10 | 3.2 | 0 | 0 |
| Hereford (check) | 11 | 2.5 | — | 0 |

Four herds in the Willamette Valley were inspected for lice 15 days following establishment of the rubbing units. These cattle showed a decrease in louse population of 89 to 91 per cent (Table 1), but none were entirely clean at this time. After 22 to 25 days lice were found on only 3 animals out of 35 examined in 7 herds from both areas. Observations were continued for 55 days, but no live lice were found on animals after the 25th day.

*Bovicola bovis* decreased in numbers more rapidly than did *Linognathus vituli*, probably owing to differences in activity and feeding. Untreated cattle in both areas showed no decrease in lice population during the test period.

### Literature Cited

**Lindquist, Arthur W.,** and Robert A. Hoffman. 1954. Effectiveness of cattle-rubbing devices and hand dusting for horn fly control. Jour. Econ. Ent. **47**(1): 79–81.

**Rogoff, Wm. M.,** and Alvin L. Moxon. 1952. Cable type back-rubbers for horn fly control on cattle. Jour. Econ. Ent. **45**(2): 329–34.

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## House Fly Control with Residual Sprays of Organic Phosphorus Insecticides

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The increasing resistance of insects to insecticides continues to stimulate interest in research for new toxicants or ways of improving the results obtained with presently available ones. Recently several organic phosphorus chemicals have shown promise in control of insect pests. Hoffman *et al.* (1953) demonstrated in the laboratory that the effectiveness of some organic phosphorus insecticides against DDT-resistant house flies could be improved by the addition of pyrethrum-type synergists.

**Table 1.—Per cent reduction of house flies in dairy barns after treatment with organic phosphorus insecticides and additives.**

| Formulation and Dosage (Mg./Sq. Ft.) | Barn | 8 Hours | 1 Day | 2 Days | 5–7 Days | 10–14 Days | 21 Days | 28 Days |
|---|---|---|---|---|---|---|---|---|
| Diazinon | | | | | | | | |
| Em 50 | 1 | 93 | — | 36 | 69 | 0 | — | — |
| | 16 | — | — | 79 | 72 | 0 | 0 | — |
| 100 | 27 | 95 | 96 | 88 | 53 | 67 | 26 | — |
| WP 100 | 29 | 99 | 93 | 95 | 93 | 79 | 64 | 0 |
| | 44 | 94 | 90 | 90 | 78 | 67 | 45 | 15 |
| Diazinon+sugar | | | | | | | | |
| Em 50+200 | 2 | 100 | — | 92 | 93 | 49 | 0 | — |
| 100+200 | 28 | 100 | 99 | 97 | 87 | 60 | 0[1] | — |
| 100+400 | 38 | 97 | 85 | 70 | 12 | 0[1] | 0[1] | — |
| WP 100+200 | 32 | 100 | 99 | 97 | 88 | 65 | 29 | 0[1] |
| Diazinon+piperonyl butoxide | | | | | | | | |
| Em 50+200 | 18 | — | — | 99 | 97 | 29 | 0 | — |
| WP 25+125 | 23 | 100 | 100 | 98 | 99 | 96 | 37 | 45 |
| | 26 | 97 | 74 | 83 | 33 | 0 | — | — |
| 50+200 | 30 | 100 | 88 | 80 | 80 | 33 | 28 | 25 |
| Diazinon+sulfoxide | | | | | | | | |
| Em 50+200 | 17 | — | — | 80 | 0 | 0 | — | — |
| | 12 | — | — | 87 | 85 | [2] | — | — |
| 100+200 | 45 | 95 | 86 | 85 | 72 | 30 | — | — |
| 100+400 | 42 | 93 | 90 | 84 | 79 | [3] | — | — |
| Diazinon+piperonyl butoxide +sugar | | | | | | | | |
| Em 50+200+200 | 11 | — | — | 87 | 86 | 18 | 0[1] | 0 |
| | 22 | 99 | — | 96 | 81 | 95 | 20 | — |
| 100+200+200 | 31 | 100 | 99 | 88 | 95 | 88 | 57 | 44 |
| WP 100+200+200 | 34 | 100 | 98 | 98 | 94 | 89 | 70 | 86[3] |
| Bayer 21/199 | | | | | | | | |
| WP 50 | 21 | — | 55 | 61 | 27 | 0 | 0 | — |
| 100 | 25 | — | 85 | 88 | 75 | 15 | — | — |
| Bayer 21/199+sugar | | | | | | | | |
| WP 50+200 | 33 | 70 | 60 | 67 | 57 | 36 | 0 | — |
| Bayer 21/199+piperonyl butoxide | | | | | | | | |
| WP 50+200 | 24 | 99 | 97 | 90 | 94 | 93 | 21 | — |
| 100+200 | 35 | 55 | — | 35 | 15 | — | — | — |
| | 36 | 74 | 37 | 10 | 0 | — | — | — |
| Bayer 21/199+piperonyl butoxide +sugar | | | | | | | | |
| WP 100+400+400 | 40 | — | 75 | 56 | 2 | 0 | — | — |
| Chlorthion | | | | | | | | |
| Em 100 | 43 | 55 | — | 35 | 54 | 0 | — | — |
| 200 | 39 | 90 | — | 78 | 34 | 20 | — | — |
| WP 50 | 19 | — | — | 57 | 24 | 0 | — | — |
| L-13/59+sugar | | | | | | | | |
| Em 50+400 | 37 | 98 | 87 | 79 | 34 | 0[1] | — | — |
| 100+400 | 41 | 95 | 88 | 25 | 31 | 0[1] | — | — |

[1] Dead and dying flies observed but control not obtained.
[2] Owner discontinued use of milking parlor and removed attractants.
[3] Temperature cool, flies were active on outside of building only in sun.

The present paper reports field tests of several of the new organic phosphorus insecticides applied, with and without synergists, as residual sprays in barns.

Materials and Methods.—Diazinon (0,0-diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl thiophosphate), Bayer 21/199 (3-chloro-4-methyl-umbelliferone 0,0-diethyl thiophosphate), chlorthion (0-0-Dimethyl-0-(3-chloro-4-nitrophenyl)-thiophosphate), Bayer L-13/59 (a dialkyl phosphonate), malathion, and NPD (tetra-n-propyl dithionopyrophosphate) were applied as toxicants alone and in combination with sugar, piperonyl butoxide, or sulfoxide. The sugar was added as a bait, the last two materials as synergists. Formulations of both wettable powders and emulsifiable concentrates were used according to their availability.

Typical unscreened buildings in the central San Joaquin Valley of California, having one-fourth to one-half of the wall area open, were utilized in the tests. The sprays were applied with a small, low-pressure gear pump equipped with an adjustable nozzle attached to a 5-foot length of brass pipe. The long-nozzle arrangement made it possible to reach the peaks of barns with a relatively fine spray pattern and at the same time to keep the spray material at a safe distance from the operator.

Fly populations were ascertained by counting the flies alighting on a 6- by 12-inch piece of 8-mesh hard ware cloth placed upon two petri dishes containing equal parts of malt extract and water. In addition, counts were taken at permanently marked locations

on walls or ceilings and with an 18-inch Scudder-type grid to obtain substantiating evidence of the population trends. Pretreatment counts were made on the day prior to and on the day of treatment. Observations were made after 8, 24, and 48 hours and then weekly until the treatment failed. The degree of control was computed with regard to the difference in the count of flies as indicated by the three methods mentioned above before and at intervals after treatment.

Three typical barns were maintained as untreated controls in order to follow the seasonal trend of the fly populations. These populations were reasonably stable from the latter part of June until early in September.

RESULTS.—The results of these tests are summarized in table 1. Diazinon alone at either 50 or 100 mg./sq. ft. gave a high initial mortality in all tests. Applied as an emulsion at 50 mg./sq. ft. in two tests, the control deteriorated rapidly and was completely ineffective after 14 days. At 100 mg./sq. ft. fair control was obtained through 14 days with both emulsion and wettable-powder formulations, and at 21 days the wettable powder treatment produced the better control.

Four treatments with Diazinon plus sugar were applied, three of which provided a reduction of 87 to 93 per cent after 1 week and 49 to 65 per cent after 2 weeks. Only barn No. 32, treated with a wettable-powder formulation, showed any measurable reduction at 3 weeks. However, in barns treated with sugar preparations a few dead or dying flies were found through 28 days of observation. As this was not the case in barns lacking sugar, it is probable that ingestion of the sugar residue was responsible.

One test (barn 23) of Diazinon plus piperonyl butoxide (wettable powder) gave excellent control through 2 weeks and partial control of 45 per cent at 4 weeks. In general, formulations of Diazinon containing piperonyl butoxide were superior in degree of control and longevity to formulations of Diazinon alone when the dosage of Diazinon was the same. However, when Diazinon alone was used at 100 mg./sq. ft., it produced slightly better results than Diazinon plus piperonyl butoxide at 50 mg./sq. ft.

Diazinon-sulfoxide combinations were no more effective than Diazinon alone.

With compound 21/199 plus piperonyl butoxide good control through 2 weeks was obtained in only one barn. All other tests of 21/199, alone or with synergist or sugar, only fair to poor control was obtained after 2 days.

In the three tests with chlorthion poor control was obtained even 1 to 2 days after spraying with 50 or 100 mg./sq. ft. When applied at 200 mg./sq. ft. initial control was 90 per cent and control after 2 days 78 per cent. Poor results were observed thereafter. Dairy animals entering the building 4 hours after spraying at this dosage were noticeably irritated by the odor.

Compound L-13/59 was used in a sugar-baited wall spray in two barns. In both barns the initial mortality was high and the control at 2 days was good, but no practical control was obtained thereafter although dead and dying flies could be observed for 2 weeks.

Malathion alone at 50 mg./sq. ft. and malathion plus sugar quickly provided a high initial mortality, but the residues were not sufficiently toxic to maintain practical control after 2 days with the pressure of new flies entering the buildings. A single test of NPD at a rate of 50 mg./sq. ft. did not provide either immediate or residual control. These latter data are not given in the table.

SUMMARY.—Field tests conducted in dairy barns in the San Joaquin Valley of California indicate that practical control of house flies, *Musca domestica* L., with residues of several phosphorus-type insecticides was not obtained for more than 2 weeks. Residues of wettable-powder formulations generally were superior to those of emulsions after the second day. The addition of sugar to the residual sprays appeared to prolong the effectiveness of the toxicants but did not attract sufficient flies to improve control noticeably. The synergist piperonyl butoxide increased the mortality of flies and longevity of residues at the dosages used, but not sufficiently to be considered of practical value. Diazinon-sulfoxide combinations showed no promise. Greater concentrations of piperonyl butoxide would appear inadvisable, but further research with formulations of wettable powders might be of value.

LITERATURE CITED

**Hoffman, Robert A.,** Theodore L. Hopkins, and Arthur W. Lindquist. 1954. Tests with pyrethrum synergists combined with some organic phosphorus compounds against DDT-resistant flies. JOUR. ECON. ENT. 47(1): 72–6.

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## Organization of a Plant Quarantine System in Okinawa

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One of the most severe battles of World War II occurred on Okinawa which nearly destroyed the food production economy of the natives. Rehabilitation of the Ryukyu population developed many problems for the United States Army and its occupation personnel. Agriculture having been the chief industry, it was important to hasten the recovery of all phases of food and fiber production so as to provide the populace with the necessary agricultural supplies. Their food crops are sweet potatoes, sugar, rice, vegetables and small grains. Fiber crops are rice straw and other grasses used for floor and wall covering and for clothing and shoes. Dried native grass is used for thatching houses.

Surveys for the presence of plant damaging pests indicated that the West Indian sweetpotato weevil *Euscepes postfaciatus* (Fairm.), was a post war introduction. Also a serious disease of sweet potatoes called Tengus virus was observed affecting plants on Miyako Gunto in the spring of 1950, and had spread southward to Yaeyama Gunto and then to the Motobu Peninsula area of Okinawa and on nearby small islands, including Ie Shima.

Another pest, the sweetpotato moth, was found attacking plants on Yaeyama Gunto. The sweetpotato weevil, *Cylas formicarius elegantulus* (Sum.), a pre-war introduction, is also prevalent, and as sweet potatoes form the chief food supply of the natives, it was important to establish a plant pest control and quarantine organization to protect this crop and to take action against pests of other crops. In the spring of 1951, the Department of Army requested the National Research Council to secure a person for this project, so, its Pacific Science Board, located in Honolulu, arranged with Mr. A. A. Brock, Director, California Department of Agriculture, for me to go to the Ryukyu Islands to study

the needs for establishing a plant protection service.

Departure was effected on August 1, 1951, with stop over visits in Hawaii and Japan, where many persons who were familiar with pest conditions in the Ryukyus gave me very helpful information. On arrival in Okinawa, additional reports concerning pests in general were received from the entomologists and pathologists sent there by the Pacific Science Board as well as from members of the Okinawa Experiment Stations.

Observations indicated that a plant quarantine and pest control structure would be necessary if the Ryukyu agricultural crops were to be protected from injurious plant pests. An Agricultural Plant Quarantine Law and Sanitary Export Certification Law, each with regulations, as well as two interior and five exterior quarantines were drafted. The interior quarantines were designed to prevent the spread of melon flies and pests of sweet potatoes, whereas the five exterior quarantines were directed against hosts of melon flies, Mediterranean fruit flies, sugarcane pests, sweet potato insects and the onion maggot. Discussions were held with members of the Civil Administration to familiarize them with methods and procedures for establishing and maintaining a plant quarantine system and for conducting pest eradication projects.

After this was completed, a meeting was held with a large committee of native agricultural leaders to discuss the results of the project. These committee members, who had assembled from each Gunto, listened to the various sections of each regulation which was read, and explained by an interpreter. When indemnification for crop losses caused by eradication was mentioned, I proposed that such losses should be borne equally by the government, the protected area, and the affected properties. This started a brisk debate in native tongue and I was soon informed by the interpreter, that the committee wished to permit *full* payment for damaged crops. They even argued that a hard working widow should be paid full value plus a *bonus*. I warned them they might find every aggrieved rancher would turn out to be a widow, which could create an expensive pattern. When the law was finally promulgated, provision was made for reimbursing property owners not to exceed two-thirds of the damage sustained, such payments to be made from Natural Resources funds budgeted annually for such purpose.

Before the war, the Ryukyus were covered by the Japanese Plant Quarantine Law which had been revised in 1950. This Ryukyu committee proceeded to voice a general objection to the style of my proposal, preferring to pattern any new set of regulations along the line of the existing Japanese Law which was cumbersome, verbose, stilted and unsatisfactory, so I explained that military movements of agricultural commodities made it important to use language and phrases which would be familiar to the United States military and occupation forces. After considerable discussion my proposal was adopted.

After reviewing the results of my first tour of duty, the Pacific Science Board meeting in Honolulu in February, 1952, decided a return visit should be made to observe the operation of the newly created plant quarantine organization. So, I returned in October, 1952, and was gratified to find a working plant quarantine organization operating efficiently. Especially since the law had only become effective February 1, 1952.

The interior quarantines covering melon flies and sweet potato pests had been promulgated, as had an exterior quarantine against the melon fly. The four other exterior quarantines were still under consideration for being activated. On this second trip, four additional exterior quarantines were recommended covering foreign areas where the following Irish potato pests occur, such as Golden nematode, tuber worm, Colorado potato beetle and potato wart.

During 1951, in an area in Central Okinawa comprising several square miles where sweet potatoes were a major crop, the vines were generally infected with Tengus virus. However, this same area was found to be remarkably free of infection in 1952, with only two infected plants visible in an area known to have had a 50 per cent infection in 1951. The clean-up had been achieved under authority of the new law and the application of sound eradication methods. The Plant Quarantine Officer, Mr. Seikei Asato is doing a good job. He has an inspection force of 22 men.

Pest control practices were outlined to Mr. Asato and the Occupation Administrative Leader, Mr. Ellis J. Kohler, as were suggestions for conducting the operation of domestic and foreign quarantines. Fumigation schedules were prepared for treating local fruits and vegetables produced in areas known to harbor fruit flies, so the products could be moved safely to uninfested localities. Simplification of the language of portions of the "Law" was recommended to the legal staff and many other phases of enforcement practices were explained.

Reports covering commodity treatments as well as plans and specifications for constructing and operating fumigation chambers have been supplied the occupation officials. Arrangements have been made with the United States Department of Agriculture for giving a quarantine training course to Mr. Asato, Chief Plant Quarantine Officer, and other members of his staff. The Plant Protection Organization of the Ryukyu Islands is now well established and can be expected to operate satisfactorily.

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## Indications of Lygus Resistance to DDT in Washington

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DDT has been used extensively for lygus bug control in central Washington's alfalfa seed area since 1947. Ten per cent DDT dust at 20 to 25 pounds per acre applied in the late bud stage has been the usual program. Often an additional application is necessary and DDT is commonly used again, although 10 per cent toxaphene dust at 25 pounds per acre has been popular. The three principal species of lygus bugs, reported by Malcolm (1953), common in alfalfa fields of central Washington are *Lygus elisus* Van D., *L. hesperus* Knight, and *L. desertus* Knight. *Lygus elisus* was found in the fields in greatest numbers during mid-season. During the 1952 and 1953 seasons many cases of poor lygus control occurred following the use of DDT in the Yakima Indian Reservation area of the Yakima Valley. At least four different sources of material, dust and spray, and both air and ground applications were involved. These poor results obtained, on a rather large acreage in various fields, have emphasized the possibility that lygus bugs have developed some resistance to DDT.

Careful field work in over 7,000 acres of alfalfa grown for seed during 1952 indicated no lack in lygus control resulted from first applications of DDT.

Where subsequent control measures were necessary in July for lygus and two-spotted spider mite, a dust formulation containing 5 per cent DDT and 3 per cent Aramite at 35 pounds per acre was used. Five per cent DDT was used at this time in place of toxaphene or 10 per cent DDT because of suspected incompatibility of Aramite with toxaphene or the higher concentrations of DDT. Unfortunately after using this DDT-Aramite formulation numerous cases of only fair control, or a reduction of lygus from 3 to 5 per sweep to 1 to 2 per sweep occurred. Principally adults were left 4 to 7 days after application. One grower, using a ground duster, applied 10 per cent DDT at 25 pounds per acre and no control was evident on 75 acres treated. Both nymphs and adults were present in this field in numbers of 2 to 4 per sweep, 4 to 7 days after application. Analyses of the dust indicated there was over 10 per cent DDT present in all cases.

Since DDT was not giving adequate control, in numerous fields a dust formulation containing 10 per cent of toxaphene and 4 per cent of Aramite was used at 30 pounds per acre. This gave much better lygus control but did not compare favorably with the results obtained with the DDT used for first applications. In 12 different seed fields counts of one lygus per two sweeps, which included both nymphs and adults, were commonly found after toxaphene was used. Toxaphene usually had been giving excellent control, with only one or two lygus per 10 sweep-remaining. Aramite applied alone or in combination with DDT or toxaphene gave excellent mite control for 30 days or longer.

Anderson and Tuft (1952) reported that DDT did not give effective control of lygus bugs in seed alfalfa in southern California during periods of extremely high temperatures but that toxaphene did. High temperatures may have contributed toward the poor control obtained in Washington in 1952. However, the possibility of resistance cannot be disregarded since even poorer control was obtained in 1953 when the Yakima Valley had practically no unseasonably high temperatures. In 1953, while working in the same general area, many cases of poor control were observed. About June 15 there were two places where the treatments had to be repeated. Two manufacturers and two applicators were involved. One field had a mixture containing 50 per cent sulfur, 10 per cent DDT, and 2 per cent parathion applied by air at 30 pounds per acre. Another field had 10 per cent DDT plus 2 per cent parathion applied by airplane at 30 pounds per acre. Ten days later 50 per cent sulfur, 10 per cent DDT and 1 per cent parathion dust at 30 pounds per acre was applied on hundreds of acres and gave excellent control of the pea aphid and lygus bugs. About July 5, degree of control fell off suddenly and most growers then used a mixture containing 50 per cent sulfur, 10 per cent DDT and 2 per cent parathion at 30 pounds per acre. Good control was obtained on most fields but a few cases of only fair control occurred. A.so around July 5, liquid applications of 2 pounds of miscible DDT and 0.25 pound of actual parathion per acre, applied by airplane at 5 gallons of spray per acre, gave very poor control. By using 3 pounds of DDT and 10 ounces of parathion per acre in 5 gallons of water, application by airplane gave good results. Applications were repeated for control of lygus bugs on 200 to 300 acres because of DDT failure in 1953.

When it was time for the second lygus control program, 10 per cent toxaphene dust at 30 pounds per acre was used. To obtain excellent initial control 15 per cent toxaphene dust at 30 pounds per acre was used. In a few cases, even this dosage did not seem to give very good control after 2 weeks. *Lygus* spp. were collected at various times in fields where control was poor in 1952 and 1953; nearly all were identified as *L. hesperus*. Perhaps this species is showing a greater degree of resistance to DDT than the others. Careful research is needed to determine the degree of resistance and to evolve a better control program.

LITERATURE CITED

**Anderson, L. D., and T. O. Tuft. 1952.** Toxicity of several new insecticides to honey bees. JOUR. ECON. ENT. **45(3):** 466–9.

**Malcolm, David R. 1953.** Host relationship studies of lygus in south central Washington. JOUR. ECON. ENT. **46(3):** 485–8.

## Malathion and Chlorthion for Control of Insects Infesting Stored Grain

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Various dusts such as lime, ashes, sulfur, and silica have been employed to prevent insect infestation in stored grain. More recently protectant dusts have been effectively used that incorporate an insecticide which is toxic to the insect but relatively harmless, in the amounts used, to warm-blooded animals. Such materials as pyrethrin, piperonyl butoxide, DDT, and BHC have been formulated into dusts and applied to grain in storage. Experiments conducted with malathion and chlorthion (0,0-dimethyl 0-4-nitro-3-chlorophenyl thionophosphate) dusts and sprays indicate these materials may also be effective in protecting grain from insect infestation.

Whole kernel wheat was treated with malathion or chlorthion either as a dust or a spray. The effectiveness of these materials was tested by confining 100 adults of each of the granary weevil, *Sitophilus granarius* (L.); the rice weevil, *S. oryza* (L.); and the lesser grain borer, *Rhyzopertha dominica* (F.) in 250 gram samples of treated grain initially on treatment and at monthly intervals. The insects were exposed for a period of 10 days and removed and checked for mortality. Preliminary exposure tests indicated that the maximum effect was usually obtained within 10 days. Control samples were run concurrently and used in determining net mortality by Abbott's formula.

It is observed from table 1 that the rice weevil, granary weevil, and lesser grain borer, when exposed to malathion-treated grain, were killed at dosages as low as two parts per million, and after storage for 3 months, depending on the dosage used, the kill of these insects was relatively high especially when applied to the grain as a dust. Six to 7 months after application, 8 and 16 parts per million are still effective. Although oviposition in the treated wheat by the insects prior to death was not checked, in cases where 100 per cent mortality was obtained there was no evidence of breeding 4 months after treatment. The dust treatment appeared to be more effective than the spray treatment. Of the three insects tested, *Rhyzopertha dominica* appeared to be the most resistant, and *Sitophilus oryza* the most susceptible to malathion. Tests now in progress indicate the residual effectiveness of the malathion treatment may be affected by the moisture content of the grain.

Preliminary tests with chlorthion-treated grain indicate this material to be effective against the in-

sect species tested. Chlorthion dust incorporated in wheat at the rate of four parts per million killed 100 per cent of the rice and granary weevils, and 93 per cent of the lesser grain borer, while at two parts per million, 100 per cent of the rice weevils were killed and 77 and 45 per cent of the granary weevil and lesser grain borer, respectively. The relative susceptibility of the three species of insects to chlorthion-treated grain was similar to that of malathion-treated grain.

## Effect of Certain Protectants on Germination of Wheat[1]

DONALD A. WILBUR[2]

A major research program to determine the effectiveness of insecticidal dusts in preventing damage to wheat by grain-infesting insects has been in progress at Kansas State College since June 1950. The insecticides studied consisted of various amounts and combinations of piperonyl butoxide, pyrethrins, and allethrins impregnated in pulverized wheat. Tests were conducted in the stored grain insect laboratory at Kansas State College and in more than 300 farm bins on central Kansas farms.

One of the first questions asked by prospective farmer cooperators before permitting treatment of their wheat with the experimental insecticides concerned the effects of the insecticide upon germination. Therefore, 362 germination tests of treated and untreated wheat maintained under various combinations of environmental conditions were conducted to determine any adverse effects that these insecticidal dusts might have on germination. All wheat samples were submitted to the Kansas State Board of Agriculture Seed Laboratory at Manhattan, Kansas, where the germination tests were made.

VARIABLE FACTORS.—*Formulations.*—Six important variable factors, taken alone and in combination with the others, were considered in planning the germination tests. The following insecticidal formulations were used: T-460 consisting of 1.1 per cent piperonyl butoxide and 0.08 per cent pyrethrins impregnated in pulverized wheat. This is a commercial product known as Pyrenone Wheat Protectant; T-473 consisting of 1.7 per cent piperonyl butoxide and 0.17 per cent allethrins impregnated in pulverized wheat; T-474 consisting of 1.4 per cent piperonyl butoxide and 0.04 per cent pyrethrins and 0.085 per cent allethrins impregnated in pulverized wheat; and T-475 consisting of 1.1 per cent piperonyl butoxide and 0.08 per cent pyrethrins impregnated in 50 per cent pulverized wheat and 50 per cent corncob flour.

*Rates of Application.*—The insecticides were applied to the wheat at the following rates per 1000 bushels: 200, 500, and 800 pounds. Thus the germination tests were made with wheat treated at dosage rates of from 2.6 to 10.7 times greater than the 75 pounds dosages recommended for commercial application.

*Moisture Content.*—Since the moisture content of grains generally is closely related to the effectiveness of insecticides, including fumigants, duplicate tests were made of all treatments using wheat of approximately 11 per cent and 14 per cent moisture.

*Length of Exposure.*—Treated wheat subjected to all the variables of the tests was retained in duplicate series for 15 and 45 days.

*Temperatures.*—Triplicate series of all variables were conducted at 40° F., 80° F., and 100° F. To secure the 40° F. temperature, treated samples were stored in the cold room of the College Department of Horticulture. The stored grain insect rearing room served for the 80° F. temperature. Stairs above the college power plant provided the 100° F. temperature.

*Varieties.*—The varieties of wheat tested included certified Triumph and certified Pawnee, both of which have stable germination qualities, and certified Comanche, which has weaker germination characteristics.

PROCEDURE.—For each series of tests, 8 pounds of wheat was divided into lots of 4 pounds each. The moisture content of one lot was adjusted to 11 per cent; of the other to 14 per cent. The wheat at each moisture level was treated with one of the protectant formulations at the desired rate of application.

Each pound sample of treated wheat and untreated wheat was divided into six approximately equal lots. Units of three lots for each moisture level, rate of application, and length of exposure were

[1] Contribution No. 626 Department of Entomology. Studies conducted at the Kansas Agricultural Experiment Station, Manhattan, in connection with Commercial Project No. 94 using grant-in-aid funds provided by the U. S. Industrial Chemical Co.
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**Table 1.—Effectiveness of malathion-treated grain[1] on the control of adults of *Sitophilus oryza*, *S. granarius*, and *Rhyzopertha dominica*.**

| TREATMENT | PER CENT KILL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | | | 1 Month | | | 2 Months | | | 3 Months | | |
| | *S. oryza* | *S. granarius* | *R. dominica* | *S. oryza* | *S. granarius* | *R. dominica* | *S. oryza* | *S. granarius* | *R. dominica* | *S. oryza* | *S. granarius* | *R. dominica* |
| 16 p.p.m. Dust | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 16 p.p.m. Spray | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 95 | 99 | 100 | 100 | 98 |
| 8 p.p.m. Dust | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 8 p.p.m. Spray | 100 | 100 | 98 | 100 | 100 | 82 | 100 | 100 | 91 | 100 | 97 | 88 |
| 4 p.p.m. Dust | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 4 p.p.m. Spray | 100 | 100 | 92 | 100 | 100 | 51 | 97 | 98 | 24 | 76 | 97 | 30 |
| 2 p.p.m. Dust | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 91 | 97 | 66 | 53 | 87 |
| 2 p.p.m. Spray | 100 | 100 | 80 | 40 | 48 | 0 | 28 | 5 | 6 | 0 | 6 | 2 |

[1] Wheat of 10 per cent moisture content.

placed in 40° F., 80° F., and 100° F. temperatures. Three of each six-lot unit were tested for germination on the 15th day of exposure. The remaining three lots were tested for germination on the 45th day of exposure.

RESULTS.—According to the reports submitted by the Seed Testing Laboratory there were no measurable differences in germination among the samples. This indicates that no single factor or combination of factors including variety, moisture, length of exposure, temperature or rates of application, had affected the germination of the wheat in measurable amounts.

## Control of Japanese Beetle Larvae with Isodrin and Endrin

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Field tests with isodrin and endrin for the control of the Japanese beetle larvae were established in 1952 in two roadway turf areas that lie between vegetable plots at the Vegetable Sub-station, Marietta, Ohio. These strips are permanent sod areas that receive considerable moisture from the irrigation system that is used to water the vegetable plots. Since this system is usually in operation during the middle of the summer when the adults are in flight, the area should be attractive to the females, especially during periods of scanty rainfall in the months of July and August. Furthermore, this area should be relatively more favorable for egg development and larval establishment and growth than the areas that are dependent upon natural rainfall.

Both insecticides were used as 18.5 per cent emulsifiable concentrates and were applied at rates of 0, 1, 5, 10, and 20 pounds of technical material per acre. The amount of emulsion necessary per plot was mixed into 3 gallons of water and applied with a hand sprinkling can. All treatments were replicated six times and randomized in the two sod strips. Each plot consisted of an area 8 by 11 feet.

Immediately after the insecticides were applied on August 8, 0.43 inches of rain fell. This was followed with 1.30 inches of rain on August 10, 0.50 inches on August 12, and 1.50 inches on August 13. During the period from August 8 to the first sampling date on September 22, 7.40 inches of rain fell. Most of this total rainfall occurred during the month of August. Accordingly, conditions were favorable for dispersing the insecticides in the soil.

All plots were sampled for grubs 45 days after application (September 22, 1952) and again 1 year later (September 30, 1953). Each sample consisted of three cores, 8 inches in diameter and 8 inches in depth, taken in a definite pattern in each plot. The results of the sampling are shown in the following table.

**Results from plots treated with isodrin and endrin on August 8, 1952.**

| Actual Toxicant per Acre in Pounds | Isodrin | | Endrin | |
|---|---|---|---|---|
| | Grubs per Sq. Ft. | | Grubs per Sq. Ft. | |
| | Sept. 22, 1952 | Sept. 30, 1953 | Sept. 22, 1952 | Sept. 30, 1953 |
| 1 | 8.5 | 0.5 | 7.0 | 0.0 |
| 5 | 1.2 | 0.0 | 1.3 | 0.0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 0.2 | 0.0 | 0.0 | 0.0 |
| Untreated | 21.8 | 22.5 | 25.5 | 20.8 |

When these data were analyzed statistically, it was found that the grub population in all treated plots was significantly different from that in the untreated plots for both sampling dates. It may also be noted that at the 1-pound rate both insecticides were more effective in the second year than in the first. This may be due to the greater effectiveness against newly hatched larvae.

SUMMARY.—The results of this experiment to date show that both endrin and isodrin at all of the rates used were highly toxic to the grubs of the Japanese beetle. In the control of the current season's grubs the treatments were effective when applied as late as August 8. However, the data indicate that the 1-pound rates were not as effective against the later stages of the insect as they were against the newly hatched larvae as shown by the nearly perfect control obtained in 1953. These results also show that the grub population for 1952 and 1953 were very similar indicating that the plots were equally favorable for grub accumulation during these 2 years.

## Insecticides for Control of the Southwestern Corn Borer

K. D. ARBUTHNOT[1] and R. R. WALTON[2]

In 1953 cooperative investigations on the southwestern corn borer, *Diatraea grandiosella* Dyar, were renewed at Stillwater, Oklahoma. The spread of this borer from 1913 to 1950 in New Mexico, Arizona, Texas, Oklahoma, Kansas, Arkansas, and Missouri has been reported by various authors (Davis *et al.* 1933, Walton & Bieberdorf 1948, Wilbur *et al.* 1950, Walkden & White 1951). Borer damage to corn has been recognized by many workers, but data on yield reduction appear to be limited to those reported by Walton & Bieberdorf (1948), who estimated crop loss at over 20 per cent for corn planted from March through May in Oklahoma. Since previous tests with insecticides were inconclusive (Davis *et al.* 1933, Walton & Bieberdorf 1948, Walkden & White 1950 unpublished), further experiments were conducted to determine the possibilities of chemical control.

Tests were made on field corn planted in May on upland soil near Stillwater for the purpose of controlling the second brood of the borer. At the beginning of treatment, the plants were 3 to 4 feet high and none of them had tasseled. The first application was made on June 29, 4 days after second-brood eggs were first found, and three subsequent applications were made at weekly intervals. When the earliest second-brood eggs were found, 45 per cent of the plants showed evidence of first-brood infestation.

The weather was generally unfavorable for applying the insecticides. Moderate to strong winds prevailed, and the plants were dry during the first two and the fourth applications. The third application was made during a calm period when foliage surfaces were moist. In the week following the second application, there was light to heavy rainfall on 4 days.

The first two spray applications were made with a portable power sprayer equipped with a hand gun having a fan-type nozzle, and the last two with a hand-operated compressed-air sprayer with a hollow-cone nozzle. All sprays were applied in concentrated form at a pressure of approximately 50 pounds per

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square inch. The discharge was directed at two sides and the top of each plant.

Dusts and granulated formulations were applied with rotary hand dust guns, with the discharge directed downward at the top of each plant. When the granules were applied, the fan speed was decreased below that used for dusts in an attempt to put most of them in the plant whorls.

The plots were 4 rows wide and 20 feet long, and were replicated four times in randomized blocks. The 5 sprays with 1 check in each replicate were tested in 1 experiment, and, in the same field, the 5 dust and 3 granulated formulations with 2 checks in each replicate were tested in another experiment.

Second-brood borer populations were determined on August 6 and 7 (15 days after the last application) by dissecting 10 plants from each plot. In the check plots 395 larvae and 52 pupae were taken from 40 plants in the spray experiment and 252 larvae and 26 pupae per 40 plants in the experiment with the dusts and the granules. Yields, larval populations, and the number of plants girdled by the borer were determined for 10 plants per plot on September 14.

Extreme drought, with consequent low yields, and first-brood injury tended to obscure the effects of injury by the second brood on yields of corn. The yield data are therefore not reported and it is believed that they contributed little to the study. The effectiveness of the various treatments in control of the borer is summarized in table 1.

**Table 1.—Effectiveness of different insecticides against second-brood southwestern corn borers on field corn, Stillwater, Oklahoma, 1953.**

| Insecticide (Figures in Per Cent) | Pounds of Toxicant per Acre-Application | Per Cent Reduction | | Per Cent of Stalks Girdled at Harvest |
|---|---|---|---|---|
| | | Aug. 6–7 | Sept. 14 | |
| Sprays: | | | | |
| Endrin 18.5 | 1.0 | 100 | 89 | 0 |
| EPN 45 | 2.0 | 99 | 78 | 2 |
| Lindane 20 | 1.0 | 99 | 78 | 0 |
| Aldrin 23.1 | 1.0 | 94 | 30 | 5 |
| Toxaphene 60 | 6.0 | 93 | 32 | 10 |
| Check | — | — | — | 15 |
| Dusts: | | | | |
| Toxaphene 20 | 9.6 | 95 | 49 | 12 |
| Methyl parathion 2.5 | 1.2 | 87 | 27 | 25 |
| Lindane 1.5 | 1.1 | 73 | 11 | 22 |
| Aldrin 2.5 | 1.2 | 72 | −5 | 30 |
| Dieldrin 2.5 | 1.2 | 58 | 3 | 28 |
| Granules: | | | | |
| Parathion 2 | 0.9 | 94 | 54 | 10 |
| Toxaphene 25 | 13.2 | 88 | 43 | 18 |
| Aldrin 2 | 1.0 | 83 | 41 | 18 |
| Check (dusts and granules) | — | — | — | 35 |

Endrin, EPN, and lindane sprays gave practically complete control of the second-brood borers. Toxaphene dust, parathion granules, and aldrin and toxaphene sprays gave 93 to 95 per cent control. Toxaphene and aldrin granules and methyl parathion, lindane, and aldrin dusts gave controls ranging from 72 to 88 per cent. The least effective material was dieldrin dust, which gave only 58 per cent control.

Sprays of lindane and aldrin were superior to dusts or granules of these materials. The treatments with toxaphene were about equally effective, but less toxicant was applied in the sprays. Aldrin granules were more effective than aldrin dust, but toxaphene granules were less effective than toxaphene dust. Parathion in a granulated formulation gave better control than a dust containing methyl parathion.

Borer populations on September 14 were still much lower in plots treated with the sprays of endrin, EPN, and lindane than in any other plots. The numbers of girdled plants in these plots were also exceptionally low. In plots receiving the other treatments borer populations and numbers of girdled plants at harvest were not much lower than in the checks and were even higher than the check in the aldrin dust treatments. Decreases in the check-plot populations between August 6–7 and September 14 were due to pupation and natural mortality. Normally the population during preparation for hibernation is reduced to approximately one borer per plant (Davis *et al.* 1933, Walton & Bieberdorf 1948, Wilbur *et al.* 1950). The September population was also modified by the development of a light third brood, which was inseparable from the second brood.

Although excellent control was obtained with the most effective treatments, the high dosages and number of applications used probably are not practicable. Further study is needed to determine if the amounts of material and number of applications can be reduced in order to develop economical control recommendations, not only for the second but also for the first brood.

### Literature Cited

**Davis, E. G., J. R. Horton, C. H. Gable, E. V. Walter, and R. A. Blanchard. 1933.** The southwestern corn borer. U. S. Dept. Agr. Tech. Bul. **388.**

**Walkden, H. H., and G. D. White, 1951.** Status of the southwestern corn borer in Kansas, Oklahoma, Missouri, and Arkansas in the fall of 1950. U.S.D.A. Ins. Pest Sur. Spec. Suppl. (1951, No. 2).

**Walton, R. R., and G. A. Bieberdorf. 1948.** Seasonal history of the southwestern corn borer, *Diatraea grandiosella* Dyar, in Oklahoma; and experiments on methods of control. Okla. Agr. Expt. Sta. Tech. Bul. **T-32.**

**Wilbur, D. A., H. R. Bryson, and R. H. Painter. 1950.** Southwestern corn borer in Kansas. Kans. Agr. Expt. Sta. Bul. **339.**

## Host Plants of the Spiny Bollworm in Iraq

R. L. Walker,[1] *U.S.D.A., Agr. Res. Serv., Entomology Research Branch,* and Albert Meymarian,[2] *Director of Entomology, Abu Ghraib Experiment Farm, Iraq*

Few references are found in entomological literature on the host plants of the spiny bollworm, *Earias insulana* (Bdv.), in Iraq. Thomas (1920) first reported a bollworm, *Earias* sp., attacking cotton in Iraq. He observed that this bollworm appeared early in the life of the cotton crop and concluded that okra was the main source of the infestation on cotton. He further observed that, when cotton and okra were planted together or contiguously, the bollworm did not attack cotton until late in the season. Rao (1921) reported that the only bollworm found on cotton in Iraq was *insulana* and that it attacked okra and certain malvaceous weeds. Walker (1952) reported

[1] On leave of absence in Iraq with the Food and Agriculture Organization of the United Nations during 1952.
[2] Deceased August 19, 1953.

briefly on the host range of the spiny bollworm in Iraq.

Studies conducted at the Abu Ghraib Experimental Farm in Iraq during the winter of 1952–53 showed that there was no true hibernation of the spiny bollworm. All stages were found in the field on one or more host plants for the period April 1952 to April 1953 with the exception of February. During this month all stages except the egg were found, and this stage undoubtedly was present on hollyhock, as immature larvae were found on the terminal shoots of this plant early in March.

To determine the host plants that might serve as carriers for the spiny bollworm during the late winter and early spring months until it could become established on cotton and okra, a preliminary study of the host range of this insect was made in 1952 and 1953.

The plants attacked and the periods during which the spiny bollworms were observed on them in the field were as follows:

| | |
|---|---|
| Cotton: | |
| Iraqi or Indian (*Gossypium herbaceum* L.) | May through January |
| American varieties of *G. hirsutum* L. | |
| Coker 100 Wilt | May through January |
| Acala | May through January |
| Egyptian (*G. barbadense* L.) Karnak | May through January |
| Okra (*Hibiscus esculentus* L.) | June through January |
| Hemp, Deccan (*H. cannabinus* L.) | October through November |
| Hollyhock (*Althaea rosea* L.) | December through May |
| Jute, Manchurian (*Abutilon theophrasti* Medic.) | September through November |
| Mallow, Little (*Malva pareiflora* L.) | February through April |
| Hibiscus, Chinese (*Hibiscus rosa-sinensis* L.) | December through May |

Other observers in Iraq have reported (unpublished) it as attacking little mallow and Chinese hibiscus.

The native Iraqi cotton is grown commercially only on a very limited scale. The Egyptian variety Karnak is grown in small plantings on one of the experimental farms. The American varieties are the commercial cottons of Iraq.

Okra is cultivated extensively in gardens and fields in the summer and early fall. Deccan hemp is found cultivated on irrigation channels around fields of summer crops. Hollyhock and Chinese hibiscus are ornamentals grown on a limited scale in gardens. Manchurian jute is grown only on an experimental basis at the present time on the experimental farms. Little mallow is a spreading annual herb common in fields, gardens, and depressions on wasteland.

Infestations on ratoon cotton were observed in April, and it is reported that in some years larvae and pupae were found in cotton bolls in the field as late as February. There are three hosts on which the spiny bollworm may be found during the period February through April—hollyhock, little mallow, and Chinese hibiscus. Limited infestations were found on hollyhock during December, January, and February; however, during March through May infestations were readily found. Examinations of several thousand plants of little mallow during the winter and spring months of 1953 failed to reveal one single infested plant; however, adults were found resting upon these plants on several occasions. No infestations were found on Chinese hibiscus.

These observations indicate that hollyhock is the only known host that may serve as an effective carrier of the bollworm during the late winter and early spring months until it can become established upon cotton and okra for another season. A further study of the host range may reveal other malvaceous plants in this country which serve as carriers during this period. As hollyhock is grown only in very limited numbers, there are probably other hosts as yet undetected.

LITERATURE CITED

**Thomas, Roger.** 1920. Report on cotton experimental work in Mesopotamia in 1918 to the Director of Agriculture, Iraq.

**Rao, Y. Ramachandra Rao.** 1921. Preliminary list of insect pests of Iraq. Iraq Dept. Agr. Memoir No. 7: 20–2.

**Walker, R. L.** 1952. FAO Plant Prot. Bul., Vol. 1, No. 3, p. 42.

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## Thrips a Limiting Factor in Grass-Seed Production[1]

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Rhodes-grass seed produced in South Texas often has a low percentage of germination. This poor germination has been attributed to various causes, such as the lack of moisture in the soil, high or low humidity, or high temperature. More often an unqualified statement has been made that the seed produced will not germinate. This production of seed with low germination has caused considerable loss to growers of Rhodes-grass seed for sale.

During 1952 and 1953 seed produced in a Rhodes-grass nursery at the Texas Agricultural Experiment Station, Substation 15, Weslaco, had a germination as low as 1 per cent. In the latter part of the 1953 season, some seed heads were cut and put into paper bags and then in a drying apparatus. Numerous thrips were observed on the bags when they were removed from the dryer. The thrips were identified as *Chirothrips mexicanus* Crawford.[2]

A casual examination of the heads in the nursery did not reveal the presence of thrips. No thrips were exposed by the usual method of tapping the infested plant parts in the palm of the hand, but when the inflorescence was examined under magnification thrips were found on the developing seed. No head was found infested before it had reached the blooming stage. Eggs were found within the inflorescence usually attached to the ovary. All stages, including pupae, were present. The thrips were feeding within the flower on the ovary and continued to feed on the developing seed through the dough stage, thus destroying the grain.

This species of thrips was found at three widely separated locations on the King Ranch, at Kingsville, Texas, and at four locations, where examinations were made, between Kingsville and Weslaco. Apparently, it is generally distributed over the Lower Rio Grande Valley on buffel-grass, Bermuda grass, Kleberg bluestem, and Angleton grass. No thrips were found on Johnson grass.

There is little published information on thrips injurious to grasses in the United States. Most of the

[1] Technical Article No. 1917, Texas Agricultural Experiment Station.

[2] Identified by Miss Kellie O'Neill, Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

reports deal with the injury to the seed heads known as silver top or with a similar injury caused by thrips feeding on the developing heads or stems within the boot.

Hewitt (1914) reported 36 per cent sterility of oats in Ottawa, Canada, caused by *Anaphothrips obscurus* (Müll.) feeding on the ovaries and anthers. Bailey (1940) reported the distribution of injurious thrips in the United States. He considered 32 species and divided them into three groups—species of major importance, species of minor importance, and species rarely injurious or reported as such very infrequently. No species of *Chirothrips* was placed in any of these groups. However, *A. obscurus* was listed as of minor importance. Bailey (1948) later published a comprehensive review of grain- and grass-infesting thrips in which he reported that *Chirothrips aculeatus* Bagn. completely destroyed the seed of fescue in increase plots at Davis, California. In this review, he listed *C. mexicanus* as occurring in California, but as being of no economic importance. He was of the opinion that thrips injure grass seed crops much more than is realized.

Roney (1949) reported that *Chirothrips mexicanus* and *C. falsus* Priesn. reduced the production of Bermuda grass seed in Arizona. Seed production was increased from 30 to 50 pounds per acre to 350 to 450 pounds by controlling the thrips with a 2 per cent parathion dust applied at the rate of 15 to 18 pounds per acre.

In the nursery at Weslaco, the thrips were blasting the seed of the Rhodes grass reducing the production of good seed. The infested mature heads were clipped to reduce the source of infestation for the later developing heads and to eliminate the already blasted seed, and a dusting program was begun. Four applications of a dust containing 10 per cent of DDT plus 2.5 per cent of dieldrin were made at weekly intervals, each at the rate of 30 pounds of the dust per acre. Three lots of ten heads each in the dough stage were collected at random over the treated area and over an adjoining untreated area. Each lot was placed in a darkened box and a record made of the number of thrips emerging into a vial inserted in the box. Later, ten heads in the dough stage were collected at random from each area and examined under a microscope. One hundred seeds from each head were observed and the numbers of sound and blasted seed were recorded. In the treated area there was on an average 2.7 thrips per head and 12.3 per cent of the seed had been blasted, as compared with 85.5 thrips per head and 91.7 per cent of the seed blasted in the untreated check area. Increased production of sound Rhodes grass seed resulted from the control of thrips with an insecticide.

Besides the large acreage of grazing land on which grasses are now seeded, the recently increased permanent and semipermanent pastures require large amounts of seed. Numerous species of grasses are being introduced through the cooperative new crops program of the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Most of these grasses adapted for general use will require production of seed for increase. Thrips may limit the survival of a continuous stand of grass by preventing the production of seed for natural reseeding as well as by destroying seed intended for harvest.

*Chirothrips mexicanus* and other grass-seed infesting thrips are widespread, and it is possible that other injurious species will slip through our quarantine stations. Andre (1941) described two species of *Chirothrips* intercepted at quarantine stations on grass seed imported from Russia. He pointed out that species of this genus tend to cling to grass seed. Living specimens are occasionally intercepted many weeks after seed are collected in other countries.

### LITERATURE CITED

**Andre, Floyd.** 1941. Two new species of *Chirothrips* Haliday with notes on *Chirothrips frontalis* Williams (Thysanoptera: Thripidae). Ann. Ent. Soc. Amer. 34(2): 451.

**Bailey, Stanley F.** 1938. Thrips of economic importance in California, Calif. Agr. Expt. Sta. Cir. 346.

**Bailey, Stanley F.** 1948. Grain and grass-infesting thrips. JOUR. ECON. ENT. 41(5): 701.

**Hewitt, C. Gorden.** 1914. Sterility in oats caused by thrips. JOUR. ECON. ENT. 7(2): 211.

**Roney, J. N.** 1949. Bermuda grass seed insects in Arizona. JOUR. ECON. ENT. 42(3): 555.

**Watson, J. R.** 1923. Synopsis and catagol of the Thysanoptera of North America. Fla. Agr. Expt. Sta. Bul. 168.

## White Grub Damage to Young Pine Plantations[1]

J. G. WATTS and JOHN B. HATCHER[2]

The larva of *Phyllophaga prununculina* (Burm.)[3] is here reported, apparently for the first time, as a rather serious pest of young pine plantations in South Carolina. There was extensive damage to pine seedlings during the summer and early fall after they had been transplanted on land out of cultivation for 2 or more years. Damage by white grubs to young pine plantations in the southeast is either exceptional or it has escaped correct diagnosis in the past. There is only scant reference to white grub damage on young plantations found in the literature. Stone & Schwardt (1943) reported that certain stands of natural hardwood reproduction and planted conifers and hardwoods in New York state were decimated by white grub activity. On the other hand, white grubs have been a problem in pine seedling nurseries since the beginning of extensive artificial reforestation. In 1935, Wakeley cited this as one of the problems in pine seedling production. Johnston & Eaton (1939) found that *P. prununculina* was one of the three species of white grubs which were of economic importance in pine nurseries in the Carolinas.

About 10,500 acres of unused land at the Savannah River Project of the Atomic Energy Commission in western South Carolina were planted to loblolly, slash and longleaf pine seedlings in the winter of 1952-53. In May the survival of all species ranged from 88 to 96 per cent while in August the survival had declined to 69 per cent for loblolly, 80 per cent for slash and 72 per cent for longleaf. The August survival counts disclosed an unexpected mortality (rain, fall had been above normal and well distributed) which resulted primarily from decimation of the root system by white grubs, mostly in the second season

[1] Technical Contribution No. 202, South Carolina Agricultural Experiment Station.

[2] Respectively, Entomologist, South Carolina Agricultural Experiment Station, Blackville, S. C. and Project Forester, Savannah River Project (U. S. Forest Service-U. S. Atomic Energy Commission), Augusta, Georgia.

[3] Determinations made independently by O. L. Cartwright, U. S. National Museum, Washington, D. C. and E. P. Merkel, Division of Forest Insects, Southeastern Forest Experiment Station, Asheville, N. C.

of growth. From this time through September it appeared that the extent of losses (5 to 10 per cent) would not seriously affect the successful establishment of the plantations. However, by early November a number of plantations which had come through the summer with 70 to 85 per cent survival had been damaged to the point where a satisfactory stand could no longer be expected. A survey revealed that some 2,750 acres had less than 40 per cent survival. On an additional 5,400 acres the grub damage was severe, but if the existing survival could be maintained it would provide a manageable stand of timber. There were over 2,000 acres which suffered relatively minor grub damage.

From some 200 soil samples sifted for grubs between November and February the population varied up to three grubs per square foot, averaging slightly less than one grub per square foot. Both first and second season grubs were present although the latter were somewhat more numerous. The life history of *Phyllophaga prununculina* is not fully known but it is believed to be similar to a related group where second or third year grubs do considerable feeding in the spring before pupation occurs (estimated May 15 to June 15). This period of spring feeding by large grubs may be critical in the 1954 survival of many seedlings damaged in the summer of 1953.

The initial damage is characterized by a yellowing of the foliage and a distinct decline in vigor of the seedlings. The attack is concentrated in the top 6 to 8 inches of soil. Below this level, if the damage was not fatal, the roots may develop normally. This was especially noticeable in the deep rooted longleaf and slash pines. On the dead and dying plants the entire secondary root system and usually a portion of the cambium of the tap root had been eaten by the grubs. There was a great deal of sub-lethal damage where the secondary root system was partially or largely destroyed but with the cambium of the tap root mostly intact. For many such plants further grub feeding or unfavorable growing conditions would probably prove fatal.

The action required on this overall reforestation project, with regard to white grubs, consisted of three parts: First, emergency action to protect the surviving seedlings. Second, emergency action to give some measure of protection to the millions of seedlings being planted in the winter of 1953–54. Third, research on methods of control which can be applied to future plantings. Large-scale demonstration control areas in damaged year-old plantations have been treated with several granulated organic insecticides. Seedlings under current planting contract were dipped in emulsions of different strengths of four organic insecticides. This dipping was done at Project Headquarters before the seedlings were issued to the contractor. Untreated check rows were planted in each field. A field experiment has been set up with insecticides, rates and methods of application as variables.

Since the discovery of white grub damage on pine plantations at the Savannah River Project, injury of a similar nature has been found at a number of other locations in the coastal plain section of the State. Also, a limited amount of damage has been observed on natural reproduction of loblolly pine.

There appears to be some difference in the degree of grub damage to the three species of pines. Loblolly, being a shallow rooted species, suffers the most serious losses, with less damage resulting on the deeper rooted slash and longleaf pines. It will be necessary to replant, either partially or completely, approximately 27.5 per cent of the 9,000 acres of loblolly and a substantially lower proportion of the 500 acres of each of the longleaf and slash. Although the majority of the plantings are on a light sandy (Norfolk) soil, some are on heavier types. There has been no observable differences in damage associated with the different soil types.

The question arises as to whether a sudden change has occurred in the feeding habits of *Phyllophaga prununculina*, or whether such feeding has probably previously escaped detection. Since the mid-1930's there have been millions of pine seedlings planted each winter in South Carolina on previously cultivated fields. They have been set on private farms and lands of paper pulp companies under conditions little if any different from those at the Savannah River Project. In a majority of cases there has been a reasonably satisfactory survival while in others the survival has been poor. In most instances, however, failures have been attributed generally to dry weather. None, so far as known, have been attributed to white grub damage. The nature of the sub-lethal grub damage is such that dry weather would substantially increase the mortality rate of seedlings.

### Literature Cited

**Johnston, H. R.** and C. B. Eaton. 1939. White Grubs in Forest Nurseries of the Carolinas. U.S.D.A. Bur. Ent. and Plant Quar. E-486.

**Stone, E. L. Jr.,** and H. H. Schwardt. 1943. White Grub Injury to Young Plantations in New York. Jour. Forest. 41(11): 842–4.

**Wakeley, P. C.** 1935. Artificial Reforestation in the Southern Pine Region. U.S.D.A. Tech. Bul. 492.

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## Effects of Demeton Soil Drenches on Peanut Pests

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Demeton, a systemic organic phosphorus insecticide, was applied as a drench in soil tests conducted in 1951 at Holland, Virginia, to determine its effectiveness against aerial and subterranean insects and the root-knot nematode, *Meloidogyne hapla* Chitwood, attacking peanuts. The foliage-attacking insects, the tobacco thrips, *Frankliniella fusca* (Hinds), and the potato leafhopper, *Empoasca fabae* (Harr.), developed in sufficient numbers on the plants for an evaluation of the systemic performance of demeton. The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, which commonly attacks the immature underground peanut pods, appeared in the plots, but was not abundant enough to cause serious injury.

Dilutions of demeton at 2, 4, 8, 16, and 32 ml. of 32 per cent concentrate per liter of water were applied to single-row plots 24 feet long and 33 inches wide. These treatments supplied, respectively, 1.0, 2.1, 4.2, 8.4, and 16.8 pounds of the toxicant per acre. Each treatment, including an untreated check, was replicated three times. Applications were made 5

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**Table 1.—Injury to Jumbo Runner peanuts by certain insects and the root-knot nematode after applications of demeton to the soil. Holland, Virginia, 1951.**

| Dosage (Pounds per Acre) | Tobacco Thrips | | Potato Leafhopper | | Southern Corn Rootworm | | Root-Knot Nematode Injury |
|---|---|---|---|---|---|---|---|
| | Leaflets Injured | Control | Leaflet Injury | Control | Plants Injured | Control | |
| | *Per Cent* | *Per Cent* | *Rating*[1] | *Per Cent* | *Per Cent* | *Per Cent* | *Rating*[1] |
| None | 32 | 0 | 3.0 | 0 | 21 | — | 2.8 |
| 1 | 32 | 0 | 2.1 | 30 | 20 | 3 | 2.2 |
| 2.1 | 32 | 0 | 2.1 | 30 | 15 | 28 | 1.7 |
| 4.2 | 14 | 56 | 1.8 | 40 | 11 | 48 | 1.3 |
| 8.4 | 7 | 78 | 0.7 | 77 | 7 | 65 | 1.2 |
| 16.8 | 1 | 98 | 0.3 | 90 | 6 | 72 | 0.2 |
| Least significant difference: | | | | | | | |
| At 5% level | 6 | — | 0.35 | — | 7 | — | 0.9 |
| At 1% level | 9 | — | 0.50 | — | 10 | — | 1.3 |

[1] 0, No injury; 1.0, light injury; 2.0, moderate injury; 3.0, heavy injury.

days before planting by pouring the drenches uniformly along the bottom of a drill-row furrow 3 inches deep. The soil was thoroughly mixed to a depth of 6 inches immediately after treatment. Jumbo Runner peanuts were planted at the rate of 50 seeds per plot row, and the plants were later thinned to 8 per row.

Counts of immature thrips were made on 20 unfolded leaves receiving each treatment. The leaves were placed in glass jars containing a drop of chloroform at the time of collection in the field. The individual leaflets in each sample were then cut off, unfolded, and put in 100 ml. of 50 per cent ethyl alcohol, thoroughly agitated, and filtered several times through a Berlese funnel. A piece of 16-mesh screen placed over the top of the funnel held back the leaves but allowed the liquid containing the thrips to pass through. Ordinary white lens paper cut to fit in the bottom of the funnel retained thrips of all stages. Upon completion of the washing and filtering process, the wet lens paper containing the thrips was removed with forceps and placed on a black gridded plate, which permitted easy counting of the insects under a low-power dissecting microscope. Recovery was not complete, but it was sufficient to provide a reasonable index of comparative populations.

Records of leafhopper injury, made on September 3, are an average of evaluations by 10 observers. Rootworm and root-knot injury records were taken by the writers at the time of harvest on October 13.

Significant systemic control of thrips was indicated at dosages of 4.2 pounds or more of demeton per acre. Significant potato leafhopper control was apparent at 1.0 pound per acre, the lowest dosage tested. Effective control of either insect, however, required the extremely high dosage of at least 16.8 pounds per acre. Injury by the southern corn rootworm was significantly reduced at 4.2 pounds of demeton per acre, but at 16.8 pounds per acre only 72 per cent control was obtained. In these tests, with the low infestation rate in the plots, demeton drenches were ineffective against the southern corn rootworm. Root-knot nematode injury was significantly reduced at 2.1 pounds per acre, but effective control was obtained only with 16.8 pounds per acre.

No significant differences in peanut and vine yield were obtained as a result of the insect and nematode control with demeton. Small necrotic lesions of nonparasitic origin were observed on the leaflets in all seedlings receiving the insecticide. Injury was slight at the lowest dosages, but was progressively more severe as the rate of application increased. The leaf lesions did not occur on foliage after mid-July. More brown pod stain was observed on peanuts from plots receiving 8.4 and 16.8 pounds of demeton per acre than on those from plots treated with lower dosages of the insecticide.

## New Insecticides for Control of the Cattle Grub

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Since 1929 derris and cube have been the most effective and most widely used insecticides for the control of the common cattle grub, *Hypoderma lineatum* (De Vill.), being used almost to the exclusion of other insecticides for this purpose. They have also been the standard for evaluating the effectiveness of other materials for cattle grub control.

In recent years the chlorinated hydrocarbon insecticides DDT, TDE, methoxychlor, toxaphene, chlordane, and lindane were tested in washes or sprays, but all these materials proved ineffective. Tests at the Kerrville, Texas, laboratory of the Bureau of Entomology and Plant Quarantine during 1953 indicate that some of the organic phosphorus insecticides are effective against the cattle grub. The results obtained with some organic phosphorus and chlorinated hydrocarbon insecticides are reported herein.

Materials and Methods.—The cattle used in these tests were predominantly Hereford, Jersey, and Angus, a few animals being crosses of these breeds. The animals ranged in age from 18 months to 5 years and perhaps older.

Two pints of insecticidal material were applied as wash to each animal. As the wash was applied the infested portion of the animal's back was brushed briskly with a stiff-bristled brush. The washes containing Diazinon (0,0-diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl) thiophosphate), Bayer 21/199 (3-chloro-4-methylumbelliferone 0,0-diethyl thiophosphate), malathion, and dieldrin were prepared from wettable-powder formulations; the wash con-

**Table 1.—Results of tests with some organic phosphorus and chlorinated hydrocarbon insecticides for control of cattle grubs.**

| Material and Per Cent Concentration | Number of Tests | Number of Animals | Number of Second Instars | | Number of Third Instars | | Average Per Cent Mortality |
|---|---|---|---|---|---|---|---|
| | | | Dead | Alive | Dead | Alive | |
| Bayer L 13/59 | | | | | | | |
| 1.0 | 7 | 13 | 16 | 1 | 59 | 9 | 88.2 |
| 0.5 | 6 | 8 | 24 | 0 | 39 | 12 | 84.0 |
| 0.25 | 5 | 7 | 10 | 2 | 29 | 18 | 66.1 |
| 0.1 | 5 | 7 | 27 | 2 | 9 | 43 | 44.4 |
| Bayer 21/199 | | | | | | | |
| 1.0 | 3 | 5 | 19 | 0 | 61 | 0 | 100.0 |
| 0.5 | 5 | 6 | 11 | 1 | 33 | 5 | 88.0 |
| 0.25 | 6 | 9 | 19 | 0 | 26 | 9 | 83.3 |
| 0.1 | 5 | 7 | 10 | 3 | 2 | 17 | 37.5 |
| Diazinon | | | | | | | |
| 0.5 | 6 | 15 | 30 | 2 | 69 | 7 | 91.7 |
| 0.25 | 7 | 7 | 24 | 3 | 66 | 13 | 84.9 |
| Malathion | | | | | | | |
| 1.0 | 1 | 1 | 1 | 5 | 0 | 12 | 5.6 |
| EPN | | | | | | | |
| 0.1 | 1 | 1 | 4 | 9 | 3 | 27 | 16.3 |
| Dieldrin | | | | | | | |
| 0.5 | 1 | 1 | 2 | 5 | 2 | 7 | 25.0 |

taining EPN from an emulsifiable concentrate; and the one containing Bayer L 13/59 (a dialkyl phosphonate) by dissolving the material in tap water at the desired concentration.

Following the established technique for determining the per cent mortality, the grubs in the first two tests were extracted 7 days after treatment. In later tests the grubs were extracted 4 days after treatment. This change in technique was necessary because of the rapid action of the phosphorus insecticides in killing the grubs and the rapid deterioration of grubs after they had died. In some tests grubs were being exuded from the cyst within 4 days. It was not deemed necessary to treat animals with derris or cube to serve as control treatments in these tests. Experience for years has been that when derris or cube containing approximately 5 per cent of rotenone is applied as a wash 90 to 100 per cent mortality of the grubs is consistently obtained.

RESULTS.—The results obtained in these preliminary tests are shown in table 1. Bayer L 13/59, Bayer 21/199, and Diazinon at the higher concentrations gave mortalities approximately equal to the mortality expected when derris or cube is used. Malathion at 1.0, EPN at 0.1, and dieldrin at 0.5 per cent gave such low mortalities in the initial test that they were not tested further.

At no time were toxic symptoms noted in any of the animals thus treated. However, it must not be assumed that these materials can be applied to cattle with complete safety.

The results of these preliminary tests are not to be considered as a recommendation of these insecticides for the control of cattle grubs. They only show that under the conditions of the tests three of the phosphorus compounds gave good control of grubs at the higher concentrations used.

## Control of *Acrobasis caryae* and *Tetranychus hicoriae* on Pecans[1]

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The pecan nut casebearer, *Acrobasis caryae* Grote, is a pest of major concern to pecan producers throughout the South. In Texas it is usually the most destructive insect attacking the nuts, particularly in orchards in the east and central portions of the state. Despite the economic importance of this pest, comparatively few growers attempt to control it. In seasons when a large nut crop is set, the depredations of the nut casebearer are utilized as a thinning operation. This practice may result in the loss of a large portion of the crop or in its total destruction when infestations are severe. Similar disastrous results may follow when the nut set is light, since oviposition is concentrated on relatively few nuts. Frequent and careful inspections of the trees must be made by the grower to determine whether the pecan crop is heavy enough to warrant spraying.

When control measures are warranted, considerable labor and spray materials are required to obtain satisfactory control, since 50 or 60 gallons of finished spray are often required to cover a large tree thoroughly. Martin (1953) states that difficulties experienced by many orchardists in controlling this insect are due in part to (1) the application of insufficient material for adequate coverage, (2) poorly timed applications, and (3) the selection of unsatisfactory insecticidal compounds. This paper is concerned with the latter factor. In 1953, experiments were conducted to determine the most effective material for the control of the first generation nut casebearer larvae before they entered the developing nuts. An orchard near Granbury, Texas, was selected to evaluate five insecticides. Parathion and DDT

[1] Technical contribution No. 1941, Texas Agricultural Experiment Station.

were incorporated as controls in the test since satisfactory results have been obtained with these materials in several pecan producing states (Martin 1952, Phillips *et al.* 1953, Hinrichs *et al.* 1953). The test was composed of four replicates. A hydraulic sprayer developing a pressure of 600 pounds per square inch was used to apply the insecticides as suspension sprays on May 22, 7 days after the first nut casebearer eggs were observed on the tips of the small nuts.

On June 11, when pupation of the first generation larvae was completed, counts were made of 100 nuts on each tree and the percentage of damaged nuts recorded. This method of evaluation is conservative since pecans which are tunneled out by the larvae may drop off shortly after they are destroyed, and, therefore, not figure in a count made at the completion of the generation. The percentage of damaged nuts in each treatment is presented on table 1.

**Table 1.—Control of the first generation pecan nut casebearer with insecticides. Granbury, Texas. 1953.**

| Materials Used | Active Ingredient Pounds per 100 Gals. | Average Per Cent Nuts Destroyed |
|---|---|---|
| DDT 50% | 1.50 | 13.4 |
| Parathion 25% | .25 | 14.8 |
| Methoxychlor 50% | 1.50 | 20.5 |
| EPN 25% | .25 | 12.7 |
| Dieldrin 50% | .25 | 33.1 |
| Check | | 63.7 |
| L.S.D. at .05 level | | 9.66 |

The following materials were equally effective in controlling the pecan nut casebearer. DDT at 1.5 lbs. active ingredient, parathion at 0.25 lb., methoxychlor at 1.5 lbs., and EPN at 0.25 lb. per 100 gallons. Dieldrin at 0.25 lb. active ingredient was the least effective material tested.

In addition to the test at Granbury, an experiment using the same materials with the exception of methoxychlor was conducted at Bastrop, Texas. Unreplicated blocks of pecan trees were sprayed for the control of the first generation nut casebearer. An infestation which destroyed 48.5 per cent of the nuts on the untreated trees was reduced an average of 97.2 per cent by the application of insecticides.

Inasmuch as the first generation attack was severe, half of each of the blocks of trees was treated on June 5 to control the second generation larvae. The same materials and rates were used for the second application. The treatments were evaluated on August 8, using the method described in a preceding paragraph. The percentage of damaged nuts in plots treated with the various materials is shown in table 2.

A treatment to control the second generation was practical under the conditions of this experiment since the nut crop was reduced 21.2 per cent on adjacent unsprayed trees.

The development of economic infestations of aphids and mites appears to follow the application of DDT to control the nut casebearer, as noted by Pierce (1953), and Bordeaux mixture for pecan scab control. A test was conducted at Bastrop to determine the effectiveness of four acaricides in controlling a pecan mite (*Tetranychus hicoriae* McG.) infestation which developed following DDT treatments applied to reduce damage by the pecan nut casebearer. The following acaricides were applied on July 27 to single tree plots in a randomized, replicated experiment: parathion, 1 lb. 25 per cent wettable powder; wettable sulfur, 6 lbs. 325 mesh; R-242 (Sulphenone), 2 qts.; and Aramite, 1 pt. per 100 gallons of water. Both of the latter materials were applied as emulsifiable concentrates containing 2 pounds of active ingredient per gallon. Mite populations were recorded periodically until September 7. Ten leaflets, selected at random from each tree, were examined in the orchard and the number of adult mites recorded. The acaricides and their effectiveness in controlling *T. hicoriae* are illustrated in figure 1.

**Table 2.—Control of the second generation pecan nut casebearer with insecticides. Bastrop, Texas. 1953.**

| Materials Used | Pounds Active Ingredient per 100 Gals. | Per Cent Nuts Destroyed: 1 Application (First Generation) | Per Cent Nuts Destroyed: 2 Applications (First and Second Generation) |
|---|---|---|---|
| DDT 50% | 1.50 | 12 | 0.5 |
| Parathion 25% | .25 | 20 | 1.0 |
| EPN 25% | .25 | 7 | 4.0 |
| Dieldrin 50% | .25 | 13 | 4.3 |
| Average | | 13.0[1] | 2.5[1] |

[1] Difference between means significant at .01 level.

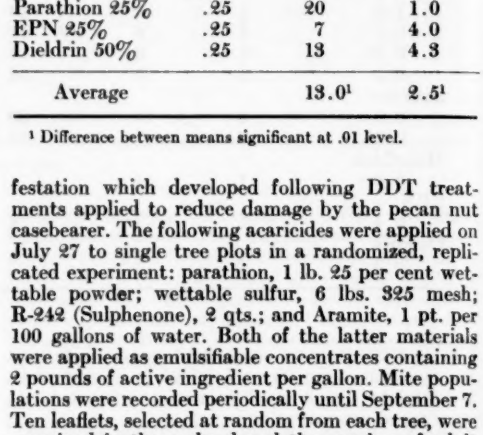


FIG. 1.—Comparative effectiveness of four acaricides in the control of *Tetranychus hicoriae* McG. on pecans.

Satisfactory control of mites was obtained for a 3-week period with parathion at 0.25 pound active ingredient and sulfur at 6 pounds per 100 gallons. R-242 (Sulphenone) and Aramite at the dosages used were less effective. Marked increases in mite populations occurred 7 weeks after the treatments were applied.

## LITERATURE CITED

**Hinrichs, Herman A., and G. A. Bieberdorf. 1953.** The pecan nut casebearer and its control. Okla. Agr. Expt. Sta. Bul. B-392.

Martin, D. F. 1952. Pecan nut casebearer control during 1947–50. Texas Agr. Expt. Sta. Progress Rpt. 1342.

Martin, D. F. 1953. Does it pay to spray pecans? Proc. Ann. Mtg. Texas Pecan Growers' Assn. 32: 44–6.

Phillips, A. M., J. R. Cole, and J. R. Large. 1952. Insects and diseases on the pecan in Florida. Florida Agri. Exp. Sta. Bull. 499.

Pierce, W. C. 1953. Studies of mites and their control on pecan in Louisiana. JOUR. ECON. ENT. 46(4): 561–5.

## 2,4-D Prolongs Life of Experimental Lemons on the Henderson Rearing Racks

F. MUNGER and B. M. BROADBENT, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

For a number of years the authors have used the Henderson rearing rack (Henderson *et al.* 1943) for holding lemons infested with California red scale, *Aonidiella aurantii* (Mask.), to be used for laboratory spray experiments. The method was modified in that the stem was clipped close to the lemon instead of being pulled off before being placed in moist sand. The stems usually separated from the lemons before the tests were completed, and spoilage, when it occurred, generally started where the stem had been attached. However, nearly all the lemons used could be held in good condition for 75 days and most of them considerably longer. This was adequate for many tests, but the advent of the organic phosphorus insecticides, which kill California red scale very slowly and have prolonged residual effects in reducing reproduction and settling of the crawling stage, made it desirable to have a way of keeping lemons for a longer time.

Packing houses had found that lemons in storage which had been treated with 2,4-D solution (Kessler *et al.* 1948, Stewart 1948) held their stems longer and were less susceptible to spoilage than untreated lemons. It was thought, therefore, that treating the laboratory host lemons with 2,4-D might increase their longevity also.

In order to test this idea, 48 green lemons were picked in Corona, Calif., on January 30, 1951. They were prepared in the usual manner by washing in tap water, dipping for 1 minute in 3 per cent sodium tetraborate solution at 90° F., and set on bottles with their stems in water. The next day 32 of the lemons were placed for 2 minutes in 2,4-D-salt solution at 68°, 16 of them in a concentration of 1–800 and 16 in 1–1600. The other 16 were left untreated. The 48 lemons were then placed on a Henderson rack and held in a conditioned room at 77° and 70 per cent relative humidity. Results of the experiment are shown in table 1.

Lemons treated with the lower concentration of 2,4-D lasted the longest time and held all their stems to the end. Of the lemons treated with the higher concentration the stem of one was lost. The untreated fruits lost all their stems.

With the life of the test lemons thus increased, the cotton pads that supply moisture to the lemons may disintegrate before the lemons spoil. Pads of spun nylon have been found to outlast the lemons. Other spun synthetic fabrics could probably be substituted for nylon, but continuous-filament fabrics do not make satisfactory wicks.

**Table 1.—Effect of 2,4-D treatment on longevity of lemons held in the laboratory on a Henderson rack.**

| CONCENTRATION OF 2,4-D | MINIMUM LIFE, DAYS | AVERAGE LIFE, DAYS | NUMBER OF LEMONS WITH STEMS ATTACHED WHEN DISCARDED |
|---|---|---|---|
| 1– 800 | 77 | 218 | 15 |
| 1–1600 | 204 | 258 | 16 |
| Untreated | 68 | 170 | 0 |

The 2,4-D treatment did not interfere with the use of the fruit as hosts for California red scale. When lemons were dipped in 2,4-D 1–1600, and infested with red scale crawlers the next day, there was no reduction in settling, and development of the scales was normal. Females that matured reproduced at the usual rate. This treatment has been adopted as standard procedure in preparing lemons to be used in rearing red scales for laboratory insecticide investigations, and lemons have been held for as long as 5 months to study effects of test materials on mortality and on reproduction and development of offspring from spray survivors.

### LITERATURE CITED

Henderson, Chas. F., Calvin L. Stucker, and Horace V. McBurnie. 1943. A laboratory method for rearing and parasitizing the California red scale for toxicological studies. U. S. Bur. Ent. and Plant Quar. ET-213.

Kessler, K. L., and J. R. Allison. 1948. Use of growth regulators on lemons in storage. Calif. Citrogr. 34(1): 24–5, 28.

Stewart, William S. 1948. Effects of 2,4-D and 2,4,5-T on citrus fruit storage. Calif. Citrus Leaves 28(11): 6–7, 24–7.

## Bee Poisoning Versus Pea Aphid Control in Alfalfa Grown for Seed[1]

C. A. JOHANSEN[2,3]

The problem of bee poisoning in alfalfa seed fields of the Yakima Valley arises from the application of insecticides to control the pea aphid. Because this insect becomes abundant during the alfalfa blooming period, treatments applied for its control are often hazardous to bees. A modification of techniques presented by Anderson & Tuft (1952) was utilized in conducting a number of field tests.

METHODS.—A measure of the direct toxicity of various insecticides to honeybees was obtained by exposing two package bee cages of 50 to 100 honeybees to each dust or spray when it was applied in the field. The residual toxicity of the chemicals was obtained by caging bees with bouquets of alfalfa

[1] Scientific Paper No. 1287, Washington Agricultural Experiment Stations, Pullman, Project No. 550.

[2] Assistant Entomologist, Washington State Agricultural Experiment Stations.

[3] Grateful acknowledgment is extended to H. S. Telford for suggestions concerning this project.

blooms cut at varying intervals after the applications. Two cages were set up for each treatment and each cage contained two bouquets taken from two replicates. All caged bees were held in a room with constant light and temperatures varying between 75 and 80° F. A 24-hour holding period was used for each time interval in the residual toxicity tests.

The relative number of pea aphids, *Macrosiphum pisi* (Kltb.), present in each replicate was determined by making 50 sweeps with a 15-inch sweeping net. All sampling, including the placing of caged bees, was conducted in the centers of the plots.

*Test I.* TEPP, Diazinon, rotenone, Q-137, and CS-708 dust formulations were applied with a power duster to a seed alfalfa field. Each material was replicated five times on plots ¼ acre in size. The results of this test are presented in table 1.

*Test II.*—Systox at 1½ pints per 10 gallons per acre

**Table 1.—Bee poisoning and pea aphid control on seed alfalfa.**

| Material[1] | Pounds per Acre | Per Cent Honeybee Mortality[2] | | | | Living Pea Aphids (Per 50 Sweeps) | |
|---|---|---|---|---|---|---|---|
| | | Dusted During Application | | Caged with Dusted Blooms | | | |
| | | 30 Min. | 24 Hr. | 1 Day | 3 Days | 1 Day | 7 Days |
| CS-780 1% | 50 | 0 | 18 | 0 | 0 | 37 | 11 |
| Q-137 5% | 35 | 0 | 29 | 32 | 0 | 31 | 9 |
| Rotenone 1% | 45 | 0 | 90 | 0 | 0 | 51 | 32 |
| Diazinon 4% | 40 | 100 | 100 | 100 | 0 | 1 | 1 |
| TEPP 1% | 65 | 100 | 100 | 0 | 0 | 0 | 1 |
| Check | | | | | | 84 | 73 |

[1] All insecticide dusts applied with a ground duster.
[2] All mortalities corrected for the check by the use of Abbott's formula.

**Table 2.—Bee poisoning and pea aphid control on seed alfalfa.**

| Material[1] | Pounds Actual per Acre | Per Cent Honeybee Mortality | | | | Living Pea Aphids (Per 50 Sweeps) | | |
|---|---|---|---|---|---|---|---|---|
| | | Sprayed During Appl. | | Caged with Sprayed Blooms | | | | |
| | | 30 Min. | 2 Days | 1 Day | 3 Days | 1 Day | 7 Days | 3 Wks. |
| CS-708 25%E | 1.0 | 0 | 0 | 3 | 0 | 72 | 14 | 38 |
| Q-137 47.3%E | 1.0 | 0 | 0 | 3 | 0 | 92 | 31 | 94 |
| Malathion 50%E | 1.0 | 0 | 71 | 22 | 15 | 64 | 5 | 12 |
| Systox 21.2%E | 0.5 | 0 | 18 | 3 | 2 | 57 | 6 | 19 |
| Check | | | | | | 209 | 171 | 265 |

[1] Insecticide sprays applied by airplane.

**Table 3.—Bee poisoning and pea aphid control on seed alfalfa.**

| Material[1] (Time of Appl.) | Pounds per Acre | Per Cent Honeybee Mortality | | | | Living Pea Aphids (Per 50 Sweeps) | | |
|---|---|---|---|---|---|---|---|---|
| | | Dusted During Appl. | | Caged With Dusted Blooms | | | | |
| | | 30 Min. | 2 Days | 14 Hr. | 3 Hr. | 1 Day | 7 Days | 4 Wks. |
| Malathion 4% (7:30 p.m.) | 40 | 0 | 100 | 1 | — | 10 | 8 | 91 |
| TEPP 1% (8:00 p.m.) | 35 | 100 | 100 | 4 | — | 10 | 12 | 103 |
| Parathion 1% (8:30 p.m.) | 35 | 0 | 100 | 0 | — | 6 | 6 | 123 |
| CS-708 5% (6:15 a.m.) | 25 | 0 | 0 | — | 0 | 27 | 11 | 104 |
| TEPP 1% (6:45 a.m.) | 35 | 7 | 40 | — | 0 | 82 | 93 | 231 |
| Toxaphene-sulfur 10%–60%) (7:15 a.m.) | 55 | 0 | 11 | — | 12 | 200 | 133 | 251 |
| Check | | | | | | 224 | 268 | 261 |

[1] Insecticide dusts applied by ground duster.

**Table 4.—Effect of aerial application of parathion-repellent combinations on insect pollinators in seed alfalfa.**

| Material | Dosage per Acre | Insect Pollinators per Thirty 10-Second Observations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Honeybees | | | Alkali Bees[1] | | |
| | | 6 Hr. | 1 Day | 2 Days | 6 Hr. | 1 Day | 2 Days |
| Parathion 25%E | 2 pt. | 6 | 17 | 26 | 1 | 1 | 8 |
| Parathion 25%E+ Carbolic Acid | 2 pt. 1 oz. | 4 | 7 | 26 | 0 | 1 | 5 |
| Parathion 25%E+ Creosote | 2 pt. 1 pt. | 1 | 8 | 27 | 0 | 1 | 5 |
| Check[2] | | 24 | 18 | 25 | 2 | 1 | 5 |

[1] *Nomia melanderi*, an important pollinator of alfalfa in the Yakima Valley.
[2] An adjacent, untreated field was used for the check.

was applied by aircraft to Kenland red clover. Direct toxicity to honeybees resulted in 26 per cent mortality after 8 hours, 100 per cent after 24. Residual toxicity measurements were 2 per cent mortality after 3 hours, and no mortality after 1 day. Clover aphids, *Anuraphis bakeri* (Cowen), present in this field were not effectively controlled by the treatment. Two-spotted spider mites, *Tetranychus bimaculatus* Harvey, were controlled.

*Test III.*—Four insecticide sprays were applied by airplane to a seed alfalfa field. Each material was replicated four times and the plots were each ¼ acre in size. Fifteen-foot buffer strips were left between the replicates. The sprays were applied at the rate of 5 gallons per acre. The results of these treatments are presented in table 2.

*Test IV.*—An alfalfa field was dusted with several insecticides with a power duster. Each treatment was replicated four times on ¼-acre plots. The results of this test are listed in table 3. Note the difference in results with TEPP applied at 8:00 p.m. at a temperature of 74° F. and applied at 6:45 a.m. at a temperature of 65° F.

*Test V.*—Two repellents in combination with parathion were applied to an alfalfa seed field. The 15-acre field was divided into three 5-acre blocks and sprayed by airplane at 5 gallons per acre. Bee activity in the plots was measured with a sighting apparatus developed by Smith & Townsend (1952). Thirty 10-second observations were made of 1-square-yard areas in each treatment at intervals following the application. Only bees actually working blossoms were counted. Table 4 indicates the results of this test.

Six hives of honeybees were placed along one edge of the treated field. No buildup of dead bees in front of these hives was observed up to 3 weeks after the application. The repellents did not change the effectiveness of the parathion against the pea aphid. The aphid population in all plots was 150 to 300 per 50 sweeps before application; 3 to 5 per 50 sweeps 3 days after application; and 13 to 26 per 50 sweeps 2 weeks after application. No serious phytotoxic effects were caused by the repellents. The foliage developed small "burned" spots after treatment, but the plants showed no general injury.

General Observations.—During these tests and observations of grower treatments, it was noted that sprays appeared to be less harmful to bees than dust. TEPP gave erratic results for several reasons, one of these being the effect of temperature. The differences obtained in honeybee mortalities and pea aphid control between the morning and evening applications of TEPP in Test IV are a striking indication of this factor. Apparently, the best results with TEPP may be obtained in the Yakima Valley during July and August with an evening treatment. Hives of honeybees were located near the fields treated in all of the tests. No increase in the number of dead bees in front of the hives was noted in any of the tests. However, the areas treated were relatively small.

Conclusions.—Three possible answers to the bee poisoning-pea aphid problem on seed alfalfa in the Yakima Valley are:

Systox applied after 6 p.m. and before 7 a.m. gave good control of the pea aphid and is appparently absorbed by the plants fast enough so that it doesn't present a hazard to bees if it is applied when they are not foraging.

CS-708 gave good control of the pea aphid and is so nearly non-toxic to honeybees that it could be safely applied at any time. Larger scale field trials are needed to confirm this.

Combinations of insecticides and repellents may be effective. Carbolic acid and creosote, in combinations with parathion, were somewhat repellent to honeybees. Higher dosages may afford a practical answer to the bee poisoning problem.

### Literature Cited

**Anderson, L. D.,** and T. O. Tuft. 1952. Toxicity of Several New Insecticides to Honeybees. Jour. Econ. Ent. **45:** 466–9.

**Davis, A. C.,** and K. G. Swenson. 1953. Evaluation of Insecticides for Pea Aphid Control. Jour. Econ. Ent. **46:** 321–3.

**Smith, M. V.,** and G. F. Townsend. 1952. A Method of Measuring Pollinator Populations on Field Crops. Can. Ent. **84:** 314–6.

## A Feeding Record of the Ten-Lined June Beetle[1]

Philip C. Johnson[2]

Adults of the ten-lined June beetle, *Polyphylla 10-lineata* (Say), were found feeding in considerable numbers during July 1948 and 1949 on the needles of ponderosa pine trees at Spokane, Washington. The area of infestation was north of the city limits in natural pine stands with sparse grass and low her-

[1] Coleoptera, Scarabaeidae.
[2] Forest Entomologist, Coeur d'Alene Research Center, Intermountain Forest and Range Experiment Station, United States Forest Service, Ogden, Utah.

FIG. 1.—Damage to ponderosa pine foliage caused by the feeding of the adult ten-lined June beetle. Note daylight resting position of beetle and curled, desiccated mid-ribs, the only part of the damaged needles not consumed.

baceous ground cover. More than one-half of the needles in lateral branch terminal clusters appeared to be eaten by the beetles. No more than one beetle per cluster was ever found (Fig. 1). The beetles began their feeding at the outer end and progressed toward the base of the needles. All but the mid-rib was consumed and this shortly assumed a straw color and grotesque curling shape from rapid desiccation. Many trees infested were among the most vigorous growing and contained the most luxurious needle growth. No trees were killed and the damage from partial defoliation was not serious.

## Greenhouse Rearing of the Soft Scale for Laboratory Screening Tests

LAWRENCE L. LEWALLEN,[1] *University of California Citrus Experiment Station, Riverside*

The soft scale, *Coccus hesperidum* L., is usually considered a minor pest of commercial citrus in California because of highly effective parasites. Field investigations have indicated that this pest sometimes attains major importance in groves treated with parathion (Elmer *et al.* 1951). These abnormal increases in soft scale populations are believed to be due to a striking resistance of this species to parathion coupled with the susceptibility of its parasites to parathion and their consequent elimination from treated groves for long periods (Bartlett & Ewart 1951).

In view of this situation, and with a look to the future of citrus spray programs, it seemed desirable to facilitate the search for suitable insecticides that may be used to control soft scale. This may best be accomplished through a laboratory screening program. In order to approximate as closely as possible the physiological condition of soft scale in the field, it seemed desirable to use some form of citrus as the host.

Rearing attempts on citrus fruits including valencia orange, lemon, and grapefruit, held at approximately 80° F. and 75 per cent relative humidity have been unsuccessful. Lemon cuttings, orange cuttings, small lemon seedlings (6 inches high), and small valencia orange seedlings (6 inches high) were also unsatisfactory. Satisfactory rearing is achieved only when valencia orange seedlings approximately 12 inches high are used. These plants at the time of infestation should be 12 to 13 months old.

Soft scale crawlers are obtained from scales reared on citron melons. The crawlers are gently brushed with a ½-inch wide, flat paint brush onto individual orange seedlings, and distributed along the trunk from the base to the tip, as well as on the under surface of the leaves. After brushing, the plants are held in a dark room maintained at approximately 80° F. and 75 per cent relative humidity for 2 days; then they are removed and placed in a greenhouse room maintained at approximately 80° F. and 65 per cent relative humidity. Under these conditions, it takes the soft scale 39 to 40 days to go through the life cycle from crawler to crawler. Mature scales reared on valencia orange seedlings average 2 mm. in length.

It is possible to reduce parasitism of greenhouse-reared soft scale by aerosol sprays of parathion once per week.

In the screening phase of this project, infested plants are sprayed when the scales are 28 to 31 days old. Mortality counts are made 2 weeks later.

### LITERATURE CITED

**Bartlett, B. R.,** and W. H. Ewart. 1951. Effect of parathion on parasites of *Coccus hesperidum* L. JOUR. ECON. ENT. **44**(3): 344–7.

**Elmer, H. S.,** W. H. Ewart, and G. E. Carman. 1951. Abnormal increase of *Coccus hesperidum* in citrus groves treated with parathion. JOUR. ECON. ENT. **44**(4): 593–7.

[1] The cooperation of Dr. B. R. Bartlett in supplying scale crawlers for this project, and R. A. Maddox in supplying orange seedlings is greatly appreciated.

# EDITORIAL

## The Chemical-Biological Coordination Center and Entomology[1]

In the October issue of the "American Scientist" Professor John P. Parker, of the English Department of Montana State College, made this trenchant comment: "With literally unlimited masses of facts, explanations, and judgments awaiting dissemination among scientists and technologists the world around, anything interfering with the ready exchange of intelligence is almost subversive." In the interests of promoting such "ready exchange of intelligence," the Chemical-Biological Coordination Center of the National Research Council has embarked on an intensive publicity program. Our guiding principles are founded on the belief that the Center has a set of files and carries out certain operations that are peculiarly, I might say uniquely, suited to a useful coordination of a great diversity of biological research.

The salient features of the CBCC may be summarized as follows: The Center is an operational group within the administrative framework of the National Research Council, which, in turn, is a part of the National Academy of Sciences. It is not connected with the Federal government. It is a non-profit organization, supported by annual grants from the Army, Navy, Atomic Energy Commission, National Cancer Institute, and American Cancer Society. The Center is advised on policy and financial matters by an Executive Committee under the chairmanship of Dr. J. G. Horsfall, Director of the Connecticut Agricultural Experiment Station. The Director of the Center is Dr. Karl F. Heumann.

The Center assembles and organizes information concerning effects of chemicals on biological systems, metabolism of test chemicals within living organisms, and mechanism of drug action and information leading to a better understanding of such action. Broadly speaking, we are interested in anything concerned with relationships between chemical structure and biological activity. The information in our files is available at no cost to all accredited scientists.

Our biology and chemistry staff members assign pertinent articles from biological literature to a staff of abstracters. The latter abstract and code the data (using the Center's specially designed biology and chemistry codes), and the data are finally transferred to IBM punch cards and filed in a multiplicity of ways. At the same time an intensive search is continually being made for unpublished data from all possible sources. The Center has a workable system for storing this information in such a way as to make it both available and useful to workers in all areas of biology. In addition to these activities, the CBCC sponsors an active screening program. The Center locates new compounds and distributes samples for testing to screening agencies in all fields of biology. The resulting data are filed after observing certain safeguards designed to protect the interests of the suppliers of the chemicals.

What each of you, as a research entomologist, wants to know is this: "How, specifically, can my work profit by the services and data which the Center is offering me?" The answer is simple: We want entomologists and other biologists to accept the Center as a research tool and to get in the habit of consulting our staff members when they have problems involving chemical-biological relationships. Admittedly, we cannot answer every question submitted. Our active files have only been accumulating for less than 3 years. In that time, for example, a start has been made in covering the biological literature from 1946 to date. But the absolute quantity of data on hand is sufficient to provide a working basis of some 130,000 separate observations of the effects of chemicals on biological systems, embracing nearly all of the major taxonomic categories of plants and animals. As your questions call attention to weaknesses in the codes and *lacunae* in the files these failings are corrected and

[1] Modified from a paper presented at the First Annual Meeting of the Entomological Society of America held at Los Angeles, Calif., Dec. 7–10, 1953.

the Center is in a better position to answer subsequent questions on similar topics.

One of the most frequent inquiries addressed to the Center is: "What kinds of questions do you answer?" The Center answers, questions concerned with selective toxicity, with the biological properties of chemicals, with the pharmacology and toxicology of given taxonomic units down to and including the species level, with sources of compounds, and, most important of all, with the correlation of structure and activity. The Center does not prepare extensive bibliographies, or conduct literature searches.

Of all the biological literature covered by the Center, articles in entomological journals have consistently proved the most difficult to abstract and code. Precise quantitative evaluations are often either lacking or are presented in terms which are scarcely codable, particularly in economic entomology. I think this might have been expected because of the nature of and practical limitations on the research itself. Much of our work on insecticide evaluation must depend on field experiments, where controlled conditions are difficult to apply. Many field test data are of basic importance and cannot be overlooked. However, when they are reported in terms of "commercial control," "% wormy heads of cabbage," or "increased or decreased crop yield," for example, the problem of how to evaluate the effectiveness of a compound in coded form becomes acute. Too often control values are omitted, or are referred to without being given. Quantitative synergistic responses are presented, with no adequate proof of synergism. Other examples might be given, but I think the point is clear. The Center does not, and tabulating machines cannot, interpret results.

I should like to offer the following suggestions, not only for the benefit of harassed editors, but in order to make published data more intelligible to those who read and use them—often without a detailed acquaintance with the author's special field. It is appropriate to note that the neglect of one or more of these items has prevented the CBCC from coding and filing many hundreds of items of chemical-biological information in recent literature.

1) Specify *test organism* (give both common and Latin names).
2) *Complete name of test compound* should be given at least once in the article.
3) Specify *concentration of test compound* in terms of active ingredient.
4) Give *dosage* as well as *concentration* where possible.
5) Give complete *formulations* where possible.
6) Specify *method of application.*
7) Specify *host organism,* or experimental environment.
8) Give quantitative data for *checks and controls,* and state when they were run. (Don't just mention that they were run.)
9) Wherever possible, evaluate results in terms of *counts* or *percentages,* rather than "indices" or "equivalents."
10) Specify whether counts are *actual* or *estimated.*
11) When a *standard* is used, always give quantitative results (not just greater than, less than, better than, poorer than, faster than, or slower than standard), and state whether standard was run *at same time* as test chemicals.
12) When giving field test data, particularly for a series of seasons or years, always give *climatic factors,* and state which treatment or series of treatments you consider the *most valid* or significant.
13) Try to *evaluate your data:* which responses, reported as either counts or percentages, are considered satisfactory, and which unsatisfactory, which treatments are, in the opinion of the author, effective and which ineffective.
14) State the *intent, summary,* and *conclusions* of the experiment as briefly and clearly as possible. Call attention to these statements by special headings or other signalling devices so that they may be found at a glance.
15) *Read your final draft* to make certain you have given all the significant and necessary information, and that all non-essential verbiage has been left out. Ask yourself (or, preferably, a colleague) if the important chemical and biological data and conclusions are presented so as to be as readily understood by botanists and pharmacologists, as by entomologists.

Our job is tremendous, but substantial progress has been made. We believe that we can successfully attain our objectives only with the active and enthusiastic support of the chemical and biological professions. The CBCC is committed to a policy of encouraging, publicizing, and aiding in research into chemical-biological relationships. There are many practical ways in which chemists and biologists can share in the Center's program. Suggestions from research workers as to (1) sources of samples of new, untested compounds, (2) sources of unpublished data, (3) publications known to contain chemical-biological data (particularly, little-known periodicals or separate publica-

tions which may not have come to the Center's attention through the usual library searching channels), (4) comments on the Center's methods and ideas for their improvement—all are not merely welcomed, but urgently solicited.

G. CONGDON WOOD, *Head, Biology Group*
*Chemical-Biological Coordination Center,*
*National Research Council*

## BOOK REVIEW

THE BEHAVIOUR AND SOCIAL LIFE OF HONEYBEES, by C. R. Ribbands. Bee Research Association Limited, 530 Salisbury House, London Wall, London, E.C. 2. 1953. (U. S. distrib.: Hale Publishing Company, Hapeville, Georgia). 352 pages, 9 plates, 66 figs. $4.50.

This book is outstanding among recent bee publications. It fills the need for an up-to-date comprehensive review in English of research on bee behavior. A work of this nature was overdue. It should appeal not only to beekeepers but to entomologists and other biological investigators desirous of having a ready reference volume that reviews and summarizes concisely the rather voluminous mass of literature in the field in question.

The author has woven together coherently and in a well-written manner résumés of about 700 references in 10 languages, interspersed with comments and interpretations giving his own views. The pattern followed in the text somewhat resembles that found in Wigglesworth's book on insect physiology. The references are by over 450 authors from some 15 countries, nearly 25 per cent of them being from the United States. v. Frisch of Germany leads in number of references cited, his total being 20. Haydak and Park of this country are tied with Ribbands for second place, each having 10 references.

The book has 38 chapters. It is not necessary to read them in sequence since each is complete in itself. The author has grouped them into four parts or sections, however, the first of which he calls, "The Roots of Behaviour." Among topics discussed in this section are the various senses of the bee, glands, and the structural differences of the castes. The second part deals with the behavior of the individual bee when outside the hive, including the way in which the worker bee finds blossoms and returns to them, its time perception, constancy in visiting flowers, how it finds its way home, and the like. The third part treats of communication among honey bees while the fourth part is devoted to various activities of bees carried on inside the hive such as brood-rearing, nectar ripening, wax production, swarming and other colony activities. The final chapter is on the evolution of the colony and contains the suggestion that social life among honey bees is the result of a "series of adaptations to a restricted food supply."

The author of this book is Principal Scientific Officer of the Bee Department at the Rothamsted Experiment Station in England. He has become known in beekeeping circles since World War II through his investigation and publications on the behavior of honey bees, especially their foraging habits. His research experience not only makes his views worthy of attention but also renders him well-qualified to evaluate the work of others in the realm of bee behavior.

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